CALIBRATION OF RADIOCHROMIC FILM IN DIFFERENT X RAY SYSTEMS IN THE RANGE OF DIAGNOSTIC RADIOLOGY

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Abstract

In this study we calibrated radiochromic films in three different X ray systems: an interventional, a conventional radiology, and an industrial system used for instruments calibration at the Instituto de Pesquisas Energéticas e Nucleares. The objective was to verify if the film sensitometric response obtained using an interventional system would be the same if it was made in a system specific for instruments calibration or in a conventional clinical equipment. The calibration procedure, which is presented by the film manufacturer, was made using the references values of tube voltage in this kind of procedure: 60 kV, 80 kV and 100 kV. The calibration curve in all three systems, for the same voltage, presented a very similar behaviour. This result is very satisfactory, because it shows that the calibration procedure can be done using a conventional X ray equipment, and an industrial system.

1. INTRODUCTION

Fluoroscopy is the study in which the physician may evaluate the internal structures with details and in real time [1]. A continuous beam of X rays is transmitted through the body part to be examined, and this image is displayed for evaluation on the monitor. In the U.S.A., fluoroscopy is the leading contributor of exposure to the U.S. population from medical imaging [2]. In 2008 a study provided a compilation of the effective doses for radiological and nuclear medicine procedures. According to this study, the effective dose in standard radiographic exams varies from 0.01 mSv to 10 mSv, in computed tomography it goes from 2 mSv to 20 mSv, and in interventional procedures the dose varies from 5 mSv to 70 mSv [3].

In order to ensure that patients, family members and patient comforters are protected in line with international radiation safety standards, using the acquired capabilities of Member States and documented optimization of patient protection, the International Atomic Energy Agency created in 2009 a project that has as one of its goals the undertaking of a survey of the patient dose in medical procedures in Latin America [4]. In this project it was proposed to evaluate the dose reference levels in interventional cardiological procedures. The radiochromic film was selected as dose measurement method due to the different regions of skin exposed to X ray. The aim of this study is to verify the film response when exposed to fluoroscopic X ray unit as recommended by the manufacturer [5] and to compare it with the sensitometric response when exposed to radiographic X ray units in order to verify if conventional clinical and industrial systems can be adopted in a calibration method.

2. MATERIALS AND METHODS

For this study we used the radiochromic film GAFCHROMIC XR-RV3, from International Specialty Products. The films were cut into strips of around 1.5 cm × 2 cm, and irradiated in two clinical X ray systems: an interventional system Philips, Allura Xper FD10 model (Figure 1a) and a conventional radiology system Philips, Compacto Plus 500 VMI model (Figura 1b). We also used an industrial X ray system, Pantak-Seifert (Figure 1c), which can generate voltage up to 160 kV and is used for intrument~~s~~ calibration at the Instituto de Pesquisas Energéticas e Nucleares (IPEN – CNEN/SP). This system has the diagnostic radiology calibration qualities established on it [6] and has traceability to the German Primary Dosimetry Laboratory, Physikalisch-Technische Bundesanstalt (PTB).

FIG. 1. The X ray systems used in this study: (a) the interventional system, (b) the conventional radiology system, and (c) the industrial system at IPEN.

To estimate the film dose in the two clinical systems, we used a dose-area product meter (DAP) from PTW, Diamentor E2 model (Figure 2a) which consists of a reading module connected to a square chamber of 141 mm × 141 mm, equivalent attenuation of 0.2 mm of aluminum, and an ionization chamber from Radcal, with 6 cm³, connected to a reading module Accu-Dose (Figure 2b). In the industrial system the dose was measured using an ionization chamber from Radcal, RC6M model, calibrated at the German Primary Dosimetry Laboratory PTB (Figure 3a), and a monitoring chamber PTW, which was used to verify the constancy of the X ray beam (Figure 3b).

FIG. 2. The instruments used for the dose measurer in the clinical systems: (a) the DAP meter, and (b) the ionization chamber Radcal.

FIG. 3. The instruments used for the dose measurer in the industrial system: (a) the ionization chamber Radcal, and (b) the monitor chamber PTW.

For the two clinical systems the ionization chamber was placed about 50 cm away from the anode spot and the DAP meter was positioned as close to the anode spot as possible. Polymethyl methacrylate (PMMA) plates were used to simulate the patient and different exposure conditions in the fluoroscopic X ray unit. A large strip of film was put after the DAP meter in order to verify the radiation field size, so it was possible to determine the dose on the film dividing the DAP measurement value by the irradiated area. Then the smaller film strips were put after the DAP meter, with the white side turned to the radiation beam (Figures 4a and 4b). For the industrial system the ionization chamber was placed one meter away, and the film 0.5 m away from the focal spot. The DAP meter was not used in this arrangement because this system already has a monitoring chamber (Figure 4c). Since this system is used for instrument calibration the radiation field size is already known, and it was not necessary to make the field mapping.

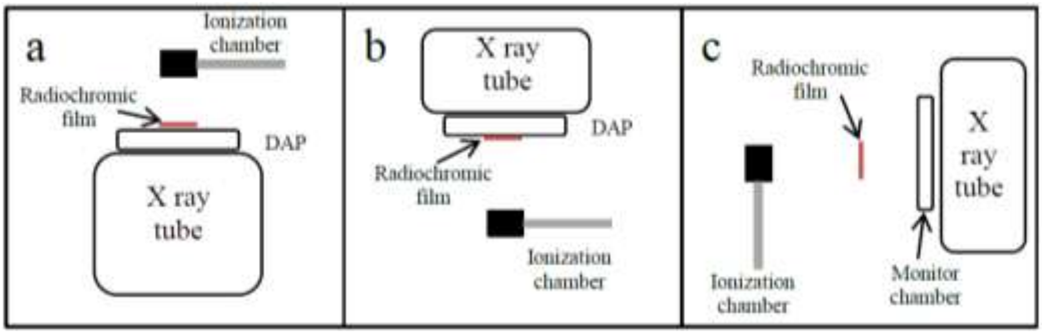

FIG. 4. Position of the DAP/monitor chamber, ionization chamber and the radiochromic films in the two clinical (a and b) and the industrial system (c).

The film optical density was read 24 hours after the exposure in a densitometer Pehamed Densoquick 2. The optical density values were related with the dose values obtained with the DAP and with the ionizing chamber.

3. RESULTS AND DISCUSSION

The films were irradiated during different periods of time, in order to obtain different doses. Table 1 shows the exposure conditions and the dose values for each X ray system.

TABLE 1. EXPOSURE PARAMETERS, FILM EXPOSURE TIME AND ACCUMULATED DOSES (ACCUM. DOSES) FOR EACH VOLTAGE AND X RAY SYSTEM.

Particulars	Philips Allura			Philips VMI			Pantak/Seifert		
Tube voltage (kV)	62	80	102	60	80	100	60	80	100
Tube current (mA)	172	895	697	300	300	300	10	10	10
Half-value layer (mmAl)	3.05	5.17	6.24	2.76	3.69	4.59	2.6	3.0	3.2
Exposure time range	6 s – 40 s	6 s – 57 s	3 s – 56 s	0.4 s –6.8 s	0.4 s –6.8 s	0.4 s –4.8 s	30 s – 14 min 18 s	32 s – 13 min 31 s	32 s – 12 min 44 s
Accum. doses (mGy)	30.5 – 154.5	152 – 1436	160 – 2190	85.5 – 1359	159 – 2683	246 – 2916	58 – 1677	96 – 2480	140 – 3468

In the Philips Allura system the exposure parameters were set automatically according to the phantom thickness, resulting in a tube current variation. In the other two systems, all the exposure conditions could be set manually.

The dose intervals were chosen, so it was possible to study different intensities of the film blackening. Unfortunately, it was not possible to obtain higher dose values in the interventional system, using the voltage of 60 kV, because the exposure time necessary to reach such doses were too long to this system, and it turned off automatically.

For the other exposure conditions, the accumulated dose range was large enough to obtain a good blackening degree of the films, with values of optical density varying from zero to 0.54, as is shown in Figure 6 (for 60 kV), Figure 7 (for 80 kV) and Figure 8 (100 kV). The energy dependence was also evaluated for a fixed dose of 1000 mGy for the industrial X ray equipment, and the result is shown in the Figure 9 (for the uncertainties in Figure 9 we considered 5% of type A and B uncertainties). From the Figures 6, 7 and 8 it is possible to note a very similar behaviour between the calibration curve obtained in the three systems, which indicates that the films can be calibrated in different X ray equipment, mainly in an industrial system with the diagnostic radiation qualities established on it, in which it is possible to get a larger exposure range. The energy dependence presented a variation of 9.2%. The industrial system was used in this case because it is possible to set exactly the tube voltage and current, and also the exposure time.

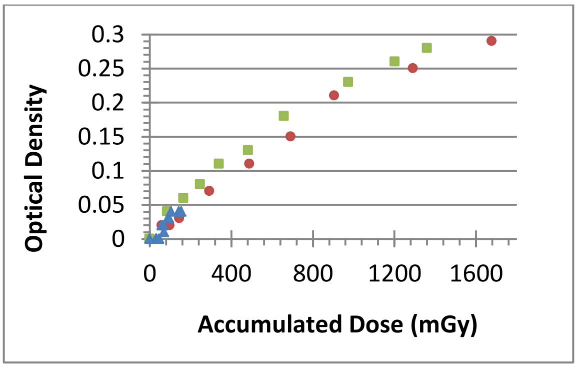

FIG. 6. Calibration curve for the radiochromic films when irradiated with 60 kV in the

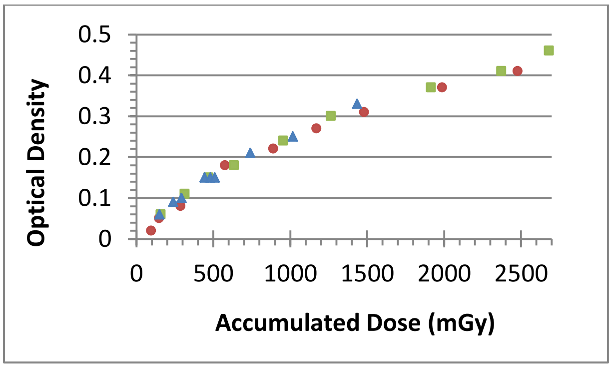

FIG. 7. Calibration curve for the radiochromic films when irradiated with 80 kV in the

interventional (blue triangle), conventional (green square) and industrial (red circle) X ray system

interventional (blue triangle), conventional (green square) and industrial (red circle) X ray system

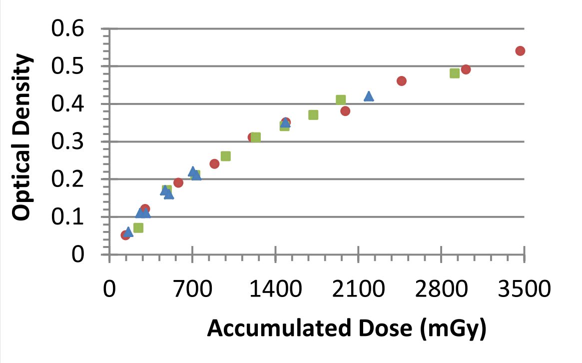

FIG. 8. Calibration curve for the radiochromic films when irradiated with 100 kV in the interventional (blue triangle), conventional (green square) and industrial (red circle) X ray systems

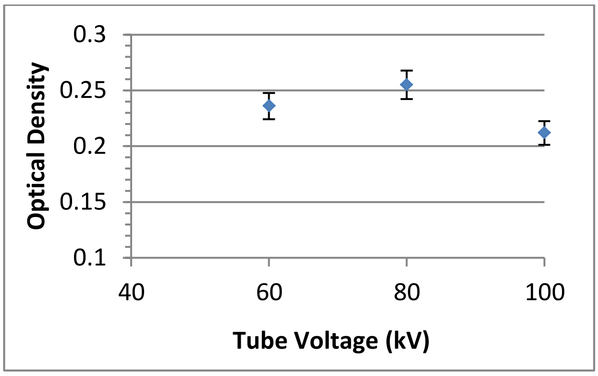

FIG. 9. Radiocromic film energy dependence for a dose of 1000 mGy. The values were obtained using the indusrial system, since it is possible to control all the exposure conditions

4. CONCLUSIONS

The doses reached in the three systems were appropriate to obtain a good blackening degree of the films, with values of optical density varying from zero to 0.54. The behaviour of the calibration curves was very similar in the three systems, mainly when using the voltage of 100 kV. This result is very satisfactory, because it shows that the calibration procedure can be adapted to different X ray equipment, even an industrial system. From the calibration curves it can be observed that the industrial and the conventional X ray systems are better to make the film calibration, since it is possible to obtain a larger exposure range.

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