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Evaluation of patients' skin dose undergoing interventional cardiology procedure using radiochromic films

Avaliação da dose na pele de pacientes submetidos a procedimentos de cardiologia intervencionista usando filmes radiocrômicos

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Abstract

In interventional cardiology (IC), coronary angiography (CA) and percutaneous transluminal coronary angioplasty (PTCA) procedures are the most frequent ones. Since the 1990s, the number of IC procedures has increased rapidly. It is also known that these procedures are associated with high radiation doses due to long fluoroscopy time (FT) and large number of cine-frames (CF) acquired to document the procedure. Mapping skin doses in IC is useful to find the probability of skin injuries, to detect areas of overlapping field, and to get a permanent record of the most exposed areas of skin. The purpose of this study was to estimate the maximum skin dose (MSD) in patients undergoing CA and PTCA, and to compare these values with the reference levels proposed in the literature. Patients' dose measurements were carried out on a sample of 38 patients at the hemodynamic department, in four local hospitals in Rio de Janeiro, Brazil, using Gafchromic© XR-RV2 films. In PTCA procedures, the median and third quartile values of MSD were estimated at 2.5 and 5.3 Gy, respectively. For the CA procedures, the median and third quartile values of MSD were estimated at 0.5 and 0.7 Gy, respectively. In this paper, we used the Pearson's correlation coefficient (r), and we found a fairly strong correlation between FT and MSD ($r=0.8334$, $p<0.0001$), for CA procedures. The 1 Gy threshold for deterministic effects was exceeded in nine patients. The use of Gafchromic© XR-RV2 films was shown to be an effective method to measure MSD and the dose distribution map. The method is effective to identify the distribution of radiation fields, thus allowing the follow-up of the patient to investigate the appearance of skin injuries.

Keywords: interventional cardiology, radiation protection, patient dose, skin dose, reference levels.

Resumo

Em cardiologia intervencionista (CI), os procedimentos de angiografia coronária (AC) e angioplastia coronária transluminal percutânea (ACTP) são os mais frequentes. Desde os anos 1990, o número de procedimentos de CI tem crescido rapidamente. Sabe-se, também, que estes procedimentos estão associados às altas doses de radiação, devido ao logo tempo de fluoroscopia (TF) e ao grande número de imagens (FC) adquiridas para documentar o procedimento. Mapear as doses na pele em CI é útil para estimar a probabilidade de lesões cutâneas, para detectar as áreas dos campos sobrepostos e registrar as áreas mais expostas da pele. O objetivo deste estudo foi estimar a dose máxima na pele (DMP) em pacientes submetidos a AC e ACTP, e compará-la com os níveis de referência propostos na literatura. As medições das doses dos pacientes foram realizadas em uma amostra de 38 pacientes no departamento de hemodinâmica, em quatro hospitais locais no Rio de Janeiro, Brasil, utilizando os filmes Gafchromic® XR-RV2. Nos procedimentos de ACTP, os valores da mediana e do terceiro quartil da DCM foram estimados em 2,5 e 5,3 Gy, respectivamente. Para os procedimentos de AC, os valores da mediana e do terceiro quartil da DCM foram estimados em 0,5 e 0,7 Gy, respectivamente. Neste trabalho, utilizou-se o coeficiente de correlação de Pearson (r) e encontrou-se uma correlação razoavelmente forte entre o TF e a DCM ($r=0,8334$, $p<0,0001$), para os procedimentos de AC. O limiar de 1 Gy para efeitos determinísticos se excedeu em nove pacientes. O uso dos filmes Gafchromic© XR-RV2 se mostrou um método eficaz para medir a DCM e o mapa de distribuição da dose. O método é eficaz para identificar a distribuição dos campos de radiação, permitindo o acompanhamento do paciente de forma a investigar o aparecimento de lesões cutâneas.

Palavras-chave: cardiologia intervencionista, proteção radiológica, dose na pele, níveis de referência.

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Introduction

The growing use of interventional cardiology procedures offers enormous benefits to patients and contributes significantly to the radiation exposure of patients[1-3]. Interventional cardiology procedures can involve high doses to patients and, in particular, to patients' skin, the tissue at greatest risk of deterministic injuries. The evaluation of skin dose from interventional cardiology procedures is recommended, but it is difficult to perform due to the different X-ray fields and projections used in the procedure[4-6]. Many studies have investigated the radiation dose to patients during interventional cardiology procedures[7-13].

The main task of radiation protection is not only to minimize the stochastic risks, but also to avoid deterministic injuries. The International Commission on Radiological Protection (ICRP) recommends the establishment of reference levels as a method of optimizing the radiation exposure[14-17].

Patient dosimetry in interventional cardiology procedures is complex due to difficulties in the identification of irradiated areas of the skin, as well as the several projections used, different field sizes, radiation qualities, focus-skin distance, and focus-image intensifier distance. These complex procedures require long fluoroscopy times and the acquisition of a large number of pictures to record the injury and its results. Mapping skin doses in interventional cardiology procedure is useful to find the probability of any skin injury, to detect areas of overlapping field and to get a permanent record of the most exposed areas of skin[11,13,18-22].

The purpose of this study was to evaluate the maximum skin dose (MSD) received by patients undergoing interventional cardiology procedures, especially because the number of procedures performed annually has increased over the past 20 years[23]. An additional purpose was to compare these values with the reference levels proposed in the literature[1,13,24-27].

Materials and methods

Institutions

Measurements were performed in four cardiac catheterization laboratories in Rio de Janeiro, Brazil: two public hospitals (A and B) and two private hospitals (C and D). The hospital A is a reference hospital in interventional cardiology procedures.

Patients

Data were obtained from a sample of 38 patients undergoing interventional procedures during coronary angiography (CA) and percutaneous transluminal coronary angioplasty (PTCA). Twenty-six CA and 12 PTCA procedures were studied. In CA, the mean patient weight was 78.3 kg (range was from 50 to 159 kg) and in PTCA the mean patient weight was 77.5 kg (range was from 58 to 120 kg). Patients were previously prepared for the procedures, according to the clinical practice of the institution and were aware of the risks and complexity of the procedure.

Radiochromic films

In this study, the patients' back MSD was evaluated using 35 x 43 cm Gafchromic XR-RV2 radiochromic films (International Specialty Products, Wayne, NJ, USA)[28,29].

Gafchromic XR-RV2 film has a higher sensitive dose range (1 cGy to 50 Gy). This film has been developed to specifically measure absorbed dose at both low and high energy photons, in which the energies are between 30 keV and 30 MeV[29]. The active layer of Gafchromic XR-RV2 is approximately 17 ?. It is sandwiched between two sheets of polyester: one transparent film substrate with thickness of 97 ? and one opaque, white film substrate with thickness of 97 ?. The transparent polyester substrate used in the film contains a yellow dye. It enhances the visual contrast of the chromatic changes when the film is exposed to radiation[29].

Each batch of films comes with a specific lot number. Therefore, each batch has a tape calibration[30].

The Gafchromic XR-RV2 film was placed on the table of procedures, under the mattress where the patient was positioned during the interventions (Figure 1).

The methodology is applied to quantify and map the dose on the patient's back. If there is a careful study of the images, one can evaluate some parameters such as geometry and irradiation conditions, distribution and intensity fields, the possible overlap of radiation fields, etc. The exposure time of each procedure was also recorded.

Statistical analysis

The Pearson correlation test was applied to assess if the MSD is linearly related to the fluoroscopy time. A p-value lower than 0.05 was considered statistically significant. All calculations were performed by using R-program statistical analysis software[31].

Results and discussion

Table 1 shows the data related to the 26 patients who underwent CA procedures. Table 2 shows the data related to the PTCA procedures.

Figure 1. Radiochromic film position.

The frequency distribution of the MSD measured with Gafchromic® XR-RV2 radiochromic films over the population of patients is shown in Figure 2.

We investigated the correlation between the various parameters (total fluoroscopy time and MSD, number of images and MSD, number of series and MSD, and patient weight and MSD) separately for the CA and PTCA to examine whether these factors could be useful in estimating the MSD during the procedures.

In the case of CA procedures, we have found a strong correlation between total fluoroscopy time and MSD ($r=0.8334$, $p<0.0001$, $r^2=0.694$). Conversely, there is a poor statistically correlation between number of series and MSD ($r=0.3573$, $p=0.07$, $r^2=0.128$), number of images and MSD ($r=0.0746$, $p=0.72$, $r^2<0.01$).

In the case of PTCA procedures, we have found a strong correlation between total fluoroscopy time and MSD ($r=0.8755$, $p=0.0009$, $r^2=0.77$). The correlation between number of series and MSD and between number of images and MSD was analyzed and a moderate correlation was found ($r=0.7525$, $p=0.0193$, $r^2=0.5662$, and $r=0.5428$, $p=0.1310$, $r^2=0.2946$, respectively).

Tables 3 and 4 show the mean values of fluoroscopy time, number of images and MSD and published data, for patients undergoing CA and PTCA, respectively.

Figure 3 shows a digital image of the Gafchromic® XR-RV2 radiochromic film used to evaluate the skin dose distribution and MSD during PTCA. In this procedure, the patients' weight was 120 kg; fluoroscopy time was 25 minutes, number of images was 1,330, and the MSD was 3 Gy.

Analyzing the correlation between fluoroscopy time and MSD, the fluoroscopy time only gives an approximate indicator of the dose to the skin. For the evaluation of MSD, it is important to consider the complexity of the procedure.

The reference levels concern: fluoroscopy time, number of images and MSD. The number of images in this study is comparable with that in other published studies for the CA procedures, but considerably higher for the PTCA procedures. The fluoroscopy time is comparable for CA procedures, but higher for PTCA. In our study, the results show an excess time spent in fluoroscopy during PTCA. Consequently, a high MSD was registered.

Conclusions

The method to identify the distribution of the radiation fields in the patient's back is effective and safe without interfering in the procedures, thus allowing the patient's follow-up in order to investigate the occurrence of skin injuries.

Although these procedures are widely justified, it is necessary that the practices are optimized to avoid unnecessary exposure of the patient. It is more important to consider that some measured values are above the threshold dose for the manifestation of deterministic effects.

Table 1. Exposure parameters in patients undergoing CA procedures

Statistical analysis	Total Fluoroscopy time [minutes]	Number of images	Number of series
Minimum	2	398	6
1st quartile	3.08	677	7
Median	5.24	1,127	10
Mean	5.98	1,297	10
3rd quartile	6.91	1,818	12
Maximum	16.5	2,602	17
Standard deviation	4.09	709	3

Table 2. Exposure parameters in patients undergoing PTCA procedures

Statistical analysis	Total Fluoroscopy time [minutes]	Number of images	Number of series
Minimum	3.6	932	14
1st quartile	16.6	1,076	16
Median	21.2	1,330	19
Mean	30.1	1,605	26
3rd quartile	33.8	1,625	33
Maximum	89.7	3,363	52
Standard deviation	24	820	13

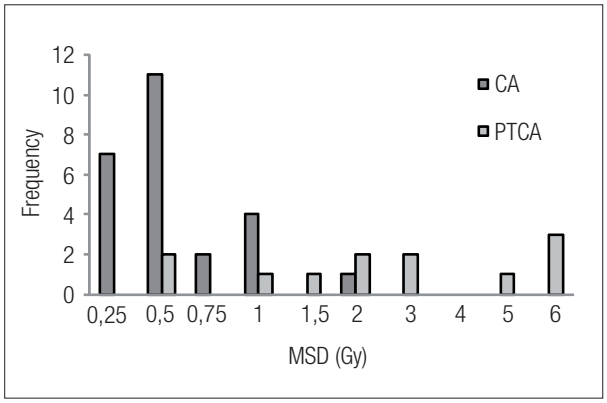

Figure 2. Frequency distribution of maximum skin dose measured by radiochromic films.

Table 3. Mean values for CA procedure

Published studies	Fluoroscopy time [minutes]	Number of images	MSD [Gy]
Neofotistou et al.[1]	6	1270	-
Giordano et al.[13]	3.80	562.5	0.09
Padovani et al.[24]	6.5	700	0.65
IAEA [25]	7.1	867.7	-
Hansson et al.[26]	9.9	1079	0.27
Trianni et al.[27]	6.2	-	0.28
This study			0.57

Table 4. Mean values for PTCA procedure

Published studies	Fluoroscopy time [minutes]	Number of images	MSD [Gy]
Neofotistou et al.[1]	16	1355	-
Giordano et al.[13]	16.20	963,5	0.49
Padovani et al.[24]	15.5	1000	1.5
IAEA [25]	15.2	1100	1.4
Hansson et al.[26]	20.3	1190	0.98
Trianni et al.[27]	13.4	-	1.03
This study	30.1	1605	3.04

Figure 3. Gafchromic® XR-RV2 radiochromic film.

If we compare our results with those proposed by IAEA research group[25], we conclude that it is imperative to carry on a trial on local practices.

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