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Assessment of patient's peak skin dose during abdominopelvic embolization using radiochromic (Gafchromic) films

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Abstract
Purpose: To assess the value of the routine use of radiochromic films in abdominopelvic embolization procedures to improve patient follow-up.
Methods: A total of 55 patients who underwent transcatheter abdominopelvic embolization were prospectively included. Six types of procedures were evaluated including hepatic chemoembolization (HCE), gonadal veins embolization (GVE), uterine elective embolization (UEE), uterine urgent embolization (UUE), abdominal elective embolization (AEE), and abdominal urgent embolization (AUE). Dosimetric indicators (DIs) such as air-kerma (AK) and kerma-area-product (KAP) were collected and peak skin dose (PSD) was measured with radiochromic films. Correlations between PSD and DIs were searched for.
Results: The mean (±standard deviation [SD]) PSD for the various procedures were: 1033 ± 502 mGy for HCE; 476 ± 271 mGy for GVE; 460 ± 171 mGy for UEE; 531 ± 263 mGy for UUE; 708 ± 896 mGy for AEE; 683 ± 392 mGy for AUE. Strong correlations were observed between PSD and DIs ($r = 0.974$ for AK and $r = 0.925$ for KAP). PSD was > 2 Gy in one procedure and all procedures (7/132) procedures resulted in AK > 2 Gy, mostly for HCE and AEE.
Conclusion: Dosimetry using radiochromic film is only appropriate for HCE, AEE and AUE, whereas dose-mapping systems present a more suitable solution for all embolizations including those with AK that occasionally exceed 2 Gy.

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Interventional radiology (IR) has become a widespread technique and its indication has increased in both elective and urgent procedures. The risk associated with x-rays should be considered, as patient skin dose can exceed the threshold of tissue reactions following long and complex procedures [1—5]. Recently, there have been many reported overexposure incidents in which tissue reactions (such as erythema, alopecia, dermatitis) causing injury have subsequently been observed [6], with skin doses to the patient frequently above 2 Gy. Therefore, IR practices must be optimized in order to reduce these risks.

The recording dosimetric indicators (DIs) is recommended to follow-up doses delivered to patients in order to prevent tissue reactions [3,6—9]. Kerma area product (KAP) or air kerma (AK) are used to assess the doses delivered to patients. The dose thresholds suggested by Stecker et al. correspond to AK greater than 5 Gy and KAP greater than 500 Gy.cm^2 [6,9,10]. However, these indicators do not give a map of the distribution of the dose and do not assess the peak skin dose (PSD) that is useful to identify potential adverse effects. A PSD greater than 3 Gy necessitates patient follow-up [6,9].

Several methods and tools have been proposed to evaluate the PSD, including thermoluminescent dosimeters, mosfet, dosimetry film, and calculation techniques [11—15]. The latter technique provides a dose map and the PSD value either in real time or retrospectively. In addition, radiochromic films are frequently used in interventional procedures [16—19]. These large-size films (sheet size 36 cm × 43 cm) supply a dose map at the end of the examination where film darkening is proportional to the dose delivered to the patient's skin.

In our institution, lower alert thresholds (AK > 2 Gy; KAP > 200 Gy.cm^2; PSD > 2 Gy) were set to improve the detection and the patient follow-up at risk of tissue reactions. In order to improve individual patient management, radiochromic films have been used since 2012 in all embolization procedures by locating the area of maximum dose exposure on the skin. If this threshold is exceeded, the patient is followed-up by the radiologist one month after the procedure. If the patient shows signs of a tissue reaction causing injury (e.g. skin erythema), they are then referred to a dermatologist.

The purpose of this study was to assess the value of the routine use of radiochromic films in abdominopelvic embolization procedures to improve patient follow-up.

Materials and methods

Population

This is a single center prospective study in which the data were acquired consecutively for all patients undergoing abdominopelvic embolization procedures from January 2016 to December 2016 using an XR-RV3 GafChromic™ film (Ashland Advanced Materials, Bridgewater, NJ, USA). This period was chosen due to the increase in the number of procedures as well as the fixed number of radiologists. Six types of procedure were studied including hepatic chemoembolization (HCE) with iodized oil (Lipiodol®, Guerbet, Roissy Charles de Gaulle, France), uterine elective embolization (UEE) for fibroids or vascular malformations, uterine urgent embolization (UUE) for postpartum hemorrhage, abdominal elective embolization (AEE) for renal tumors or renal vascular malformations, abdominal urgent embolization (AUE) for bleeding from splenic, renal, hepatic, mesenteric or hypogastric arteries and gonadal veins embolization (GVE) [20—23]. Clinical indications and arteries/veins concerned for each procedure are defined in Table 1.

For PSD measurement, patients were excluded when the film was incorrectly used or poorly centered and when the minimum detection threshold was not reached (PSD < 200 mGy). The study design is presented in Fig. 1 and the included and excluded patients for all abdominopelvic embolizations are defined in Table 2.

For each included patient, weight, height and age were recorded and the body mass index (BMI) was calculated. Procedures were performed by five experienced radiologists (between 5 and 30 years of practice). The complexity of each embolization procedure and the number of procedures per interventional radiologist are described in the Table 3.

X-ray source

All embolization procedures were performed with an Allura® Xper FD 20 (Philips, Amsterdam, The Netherland) system. This system was not equipped with the Clarity IQ (Philips) system. Low pulsed fluoroscopy mode (7.5 pulses/s) with an additional filtration of 0.4 mm Cu and 0.1 mm Al was used. For fluorography images the frame rate was 3 frames/s according to the procedure performed. The ''patient type'' (i.e., thin/small, standard, large) was automatically selected by the machine according to the patient's weight entered by the operator. This parameter has an influence on the additional filtrations used for fluorography images: 0.4 mm Cu + 1 mm Al for thin patients (from 50 to 70 kg) and 0.1 mm Cu + 1 mm Al for standard patients (from 70 to 90 kg) and large patients (> 90 kg). The x-ray system has a built-in filtration of 2.5 mm Al. No major changes (protocol optimization, software version, etc.) were made to this equipment during the study period.

Routine clinical use of radiochromic films

A reflective radiochromic film (XR-RV3, Gafchromic™) was used for each patient. Free-in air calibrations were carried out for each new batch of film as previously described [24].

Prior to the procedure, a medical radiation technologist positioned the film on the patient's back, the orange side facing the patient, in front of the abdominal region as recommended by the manufacturer. To take into account the movements of the table and the rotation of the X-ray tube, the film was positioned in landscape orientation.

After the examination, the films were stored in a support in stable conditions of temperature and humidity [25,26]. The exposed films were scanned orange side facing the scanner at one week ± 1 h post-exposure with an Epson 10,000 Expression XL under the same conditions as for the calibration: ''Professional Mode'', reflective mode, without color corrections and with a resolution of 72 dpi. The adapted calibration curve was then applied according to kVp and additional filtration used during the examination.

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