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Kerma-area product is not a useful indictor of potential tissue reactions in interventional radiology

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ABSTRACT

Potential for tissue reactions post interventional radiological procedure is well recognised. Identifying tissue reactions is not always straight forward and implementation of international guidance varies.

This single site study investigates the appropriateness of using a kerma-area product value of 500 Gy cm^2 (assumed field size 100 cm^2) to highlight potential skin injury/tissue reactions post interventional radiology procedures.

Method: Kerma-area product doses for all interventional radiological procedures over a 2 year period in a major tertiary referral hospital were retrospectively audited. A P_{KA} of 500 Gy cm^2 was used as an indicator of necessitating patient follow up for potential tissue reactions (potential peak skin dose of 3 Gy). Procedure parameters were recorded for all procedures reaching this dose. These were used to devise clinically representative phantom studies to facilitate peak skin dose measurement for each procedure identified.

Results: 5156 interventional radiology procedures were reviewed. 13 patients registered a kerma-area product dose of 500 Gy cm^2 or more. 6 patients underwent percutaneous cardiac interventions and 7 had embolization of gastro-intestinal haemorrhage.

Subsequent phantom studies representative of percutaneous cardiac interventions and embolization of gastro-intestinal haemorrhage procedures resulted in peak skin doses of 2.6 Gy and 1.5 Gy respectively for a P_{KA} value of 500 Gy cm^2.

Conclusion: A Kerma-area product of 500 Gy cm^2 alone is not a useful indicator of potential tissue reactions for percutaneous cardiac interventions or gastrointestinal haemorrhage embolization's. Extensive analysis of procedure parameters (particularly c arm movement, focus to skin distance and mean field size) post procedure is suggested to further quantify potential for tissue reaction.

Introduction

Tissue reactions have been demonstrated as a result of a range of interventional radiological (IR) procedures.[1,2] Current thinking suggests that, while they still occur, they are relatively uncommon.[3]

The fundamental basis of identifying and subsequently managing potential tissue reactions hinges on the accurate estimation of peak skin dose (PSD) in IR. Direct estimation of this is not widely clinically available[4] and it is for this reason that the National Council on Radiation Protection and Measurements (NCRP), the Conference of Radiation Control Program Directors (CRCPD) and the American College of Radiology (ACR) and American Association of Physicists in Medicine (AAPM) have suggested identical, unambiguous indirect dose parameter 'trigger values' or 'substantial radiation dose levels (SRDLs)' for the routine identification and follow up of potential tissue reactions post interventional radiological procedures.[5–7] These values are summated in Table 1 (it should be noted that the P_{KA} value is associated with a field size of 100 cm^2 at the skin surface).

The official notation of P_{KA} is suggested in ICRU report 74,[8] [also identified in the literature as dose area product (DAP) and kerma-area product (KAP)]. The IEC has standardized the unit to the

Abbreviations: Interventional radiology (IR), Kerma-area product (P_{KA}); Peak skin dose (PSD), Percutaneous cardiac interventions (PCI); Gastro-intestinal (GI), Council on radiation protection and measurements (NCRP); Nation conference of radiation control program directors (CRCPD), American college of radiology (ACR); American association of physicists in medicine (AAPM), Substantial radiation dose level (SRDL); Kerma to air at the reference point (Kar), Fluoroscopic time (FT); International commission on radiation units and measurement (ICRU), International Electro technical Commission (IEC); Dose area product (DAP), Kerma-area product (KAP).

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Table 1
International SRDLs for the identification of potential tissue reactions post IR procedures.

Parameter	Threshold for patient follow up
PSD	3000 mGy
Kar	5000 mGy
P_{KA}	500 Gy cm^2
FT	60 min

Gy cm^2.[9] P_{KA} is measured by placing an ionization chamber (large enough to completely intercept the X-ray beam) just beyond the X-ray collimators. It is a product of the surface area of the patient that is exposed to radiation at the skin entrance multiplied by the radiation dose at this surface.[10] P_{KA} is a good surrogate for the amount of energy delivered to the patient and is generally used as a predictor of the risk of stochastic effects in IR.[4] Literature varies as to its usefulness as an indicator of tissue reactions but when correlations are drawn between P_{KA} and skin doses of 2–3 Gy, trigger values or SRDL vary greatly.[11–14]

The objective of this study was to;

- Investigate the amount and type of procedures which delivered an examination P_{KA} dose of 500 Gy cm^2, or more, in a tertiary referral adult facility providing general and cardiac interventional radiology (2 Siemens Artis Zee systems, Frankfurt, Germany).
- Undertake a clinically representative phantom study for each type of procedure identified.
- Investigate subsequent actual skin dose (via phantom study) associated with procedures(s) identified.
- Comment on the appropriateness of a P_{KA} value of 500 Gy cm^2 as a SRDL for the procedures identified.

Materials and method

Dose review

Patient P_{KA} doses for all IR procedures performed were retrospectively audited for a period of over 2 years using radiology patient dose records (patient dose journals). Numbers and types of procedures with P_{KA} readings of 500 Gy cm^2 (Assumed field size 100 cm^2) or more were recorded.

Procedure review

Once procedures equalling or exceeding a P_{KA} value of 500 Gy cm^2 were identified, they were classified according to type of IR procedure. Each type of IR procedure identified was subsequently analysed in terms of operating parameters.

Operating parameters

Operating parameters included were acquisition mode, fluoroscopy pulses per second, fluorography frames per second, number of fluorographic acquisitions, total fluorography dose, total fluoroscopic dose, magnification, collimation, C Arm position and table height.

Parameters such as acquisition mode, fluorographic frame rate and fluoroscopic pulse rate will not change from a given type of procedure (dictated by procedure programme settings). Factors such as magnification, collimation, C Arm position and table height are expected to change throughout. Therefore these parameters will be considered separately for each type of procedure identified.

Magnification

The Siemens Zeego cardiac flat panel detector has 4 field sizes 25 cm, 20 cm, 16 cm and 10 cm 25 cm is considered 'full field' and 20 cm, although it is considered magnification, is not actually associated with a dose increase because it is digital magnification (verified by MMUH physics dept. QA).

The Siemens Zeego general flat panel detector has 6 field sizes 48 cm, 42 cm, 32 cm, 22 cm, 16 cm and 11 cm, again there is no dose difference between 48 cm field size and 42 cm. For both machines the first two field sizes can be considered identical in terms of dose and therefore no differentiation will be made between them.

The magnification used for each fluorographic acquisition was recorded for each procedure registering a P_{KA} dose of $\geq$500 Gy cm^2. A representative mean of these factors will be used. The actual magnification setting that is closest to the mean value was used to represent the magnification setting for the phantom study.

Collimation

Collimation was determined by actual image review of each fluorographic frame. This was achieved by using length-measuring software to establish distance between the lateral cones and craniocaudal cones. The two lengths multiplied give collimated field area for that acquisition. A mean collimated image size was determined for each type of procedure for phantom studies. Before phantom studies were undertaken, this predetermined collimated area was set up and verified using image review and length measuring applications.

C Arm position

C Arm position was be quantified in 2 planes [left/right (horizontal) and cranial/caudal (vertical)]. All definitions will be relative to the supine patient (Right Anterior Oblique, means the detector is anterior and to the right hand side of the patients body).

For the horizontal plane positions will be simplified to 4 positions (actual angles will not be recorded

- LAO (left Anterior Oblique)
- 0 (No angulation)
- RAO (Right Anterior Oblique)
- LAT (Left Lateral)

For the vertical plane, the positions will be;

- CRA (Cranial)
- 0 (No angulation)
- CAU (Caudal)

Like magnification and collimation C arm position was assessed for each fluorographic acquisition for all procedures registering a P_{KA} dose of $\geq$500 Gy cm^2. Where positions vary during a procedure the positions and percentage dose attributed to each position was analysed for each individual procedure.

A representative range of positions used and percentage of total dose attributed to each position was then established for the phantom study for each type of procedure.

Table height

Table height was established by assessing table height settings.