ESTIMATING PATIENT PEAK SKIN DOSE WITH FLUOROSCOPIC PROCEDURES

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Introduction

During image guided interventional radiology (IR) procedures, X-ray induced skin injuries may occur due to high absorbed patient skin dose. A dose metric that estimates the peak absorbed skin dose (PSD) is therefore of importance, both in terms of patient specific follow-up and for imaging protocol optimization. Action levels for skin injury follow-up are commonly based solely on the interventional reference point (IRP) cumulative air Kerma, spatially located 15 cm from the device rotational isocenter. This metric lack influence of physical dependencies to estimate PSD, e.g., irradiation geometry, conversion of air Kerma to absorbed skin dose, scattered radiation, and pre-patient attenuation. Several important irradiation event specifics are reported by radiologic equipment in the radiation dose structured report (RDSR), as described in the NEMA DICOM standard. The purpose of this work was to develop an improved dose metric, in form of an automated PSD estimation application based on RDSR data from IR procedures.

Theory

In IR, it is well established that absorbed dose and Kerma in a material, e.g. air, are equal in the presence of charged particle equilibrium. Therefore, air Kerma corrected for medium of interest and procedure specific physical dependencies are a suitable metric for skin dose estimation with IR procedures. Figure 1 illustrates an IR device in under-table configuration with source-skin-distance (SSD) equal to the patient support table's vertical offset from the X-ray source, and with IRP at fixed distance d_{IRP} from the X-ray source. When using RDSR specified IRP air Kerma for skin dose estimations, several physical dependencies needs to be addressed if high accuracy is required.

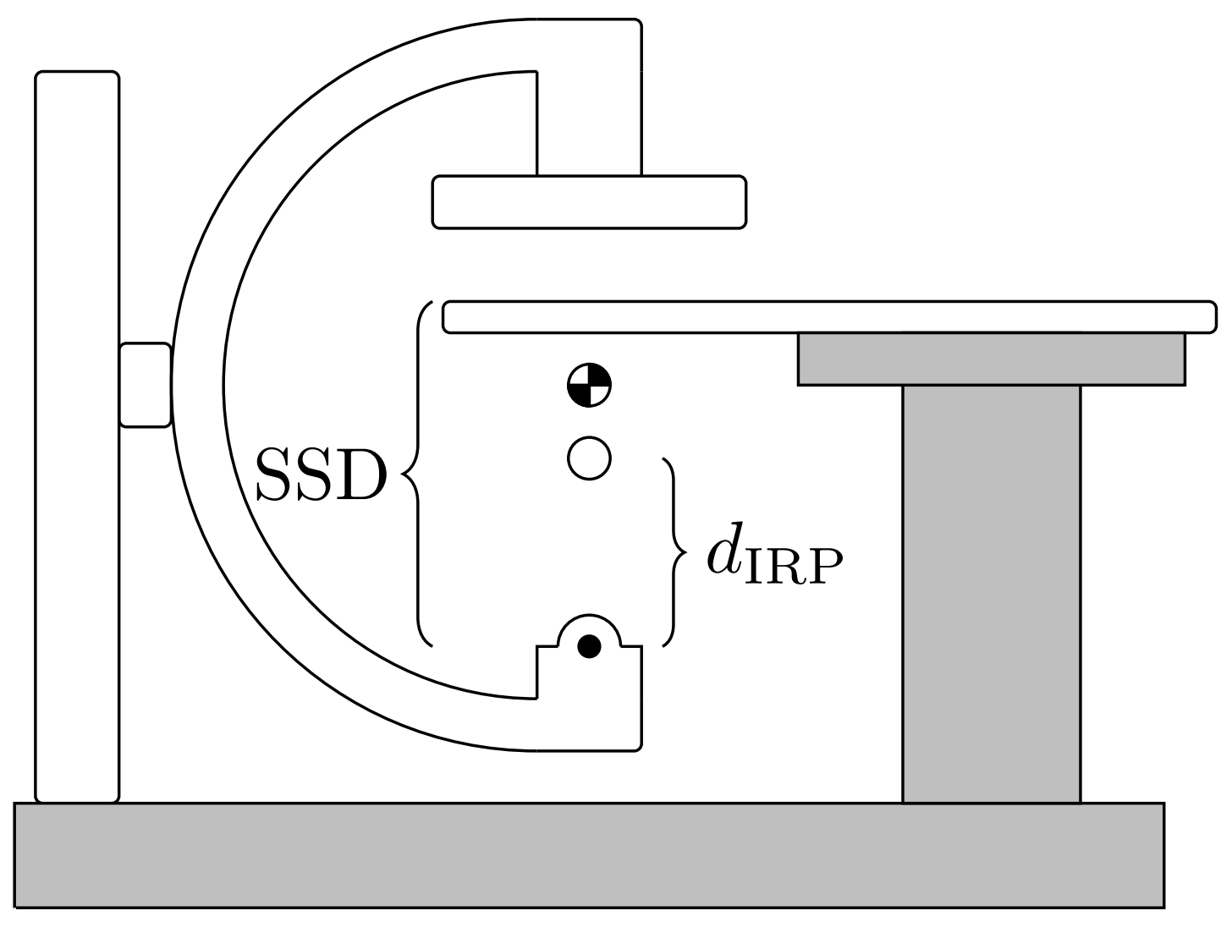

Figure 1 – Illustration of IR device in under-table tube configuration. The IRP is located 15 cm from the device rotational isocenter, in direction towards the X-ray source. Table height and angulation of the X-ray tube may, however, vary for different procedure irradiation events.

First, since the table height is set manually to a comfortable height by the radiologist on site, a significant difference between SSD and d_{IRP} might occur. This results in a difference in photon fluence between the IRP and the skin surface. Secondly, previous simulations[1] shows that a significant fraction of the skin dose come from backscattered photons from the patient. Lastly, when irradiating in under-table tube configuration, the patient support table and pad (T+P) attenuates the X-ray beam before it reaches the entrance surface of the patient.

By converting the IRP air Kerma ($K_{\text{air,IRP}}$), to water Kerma using mass energy absorption coefficients, and correcting for the above stated physical dependencies, the resulting metric improves absorbed skin dose estimations for under-table irradiations. Under the assumption that all X-ray fields overlap on the patients skin surface, the cumulative estimated maximum skin dose (ESD_{max}) from an IR procedure with N irradiation events in given by

$$\text{ESD}_{\text{max}} = \sum_{j=1}^{N} \left(D_{\text{skin}}\right)_j = \sum_{j=1}^{N} \left(\left(K_{\text{air,IRP}}\right) \prod_i k_i \right)_j$$

where the k factors correct for physical dependencies such as inverse-square-law fluence scaling, backscatter, and table attenuation for all irradiation events in the procedure. Implementation of a complete PSD model with spatial localization of all irradiation events are more complex to implement. In addition to the physical dependencies corrections, a skin dose mapping algorithm taking inputs such as beam entrance angle, field size and support table position are required for a complete PSD model.

Method

A total of four correction factors (k) were implemented in an automated workflow, converting the IRP air Kerma to skin dose in under-table irradiations. The factors were obtained by previous conducted Monte-Carlo simulations[1], RDSR irradiation event data, and support table and pad transmission measurements. The conversion from IRP air Kerma to skin dose using these factors are presented in Figure 2.

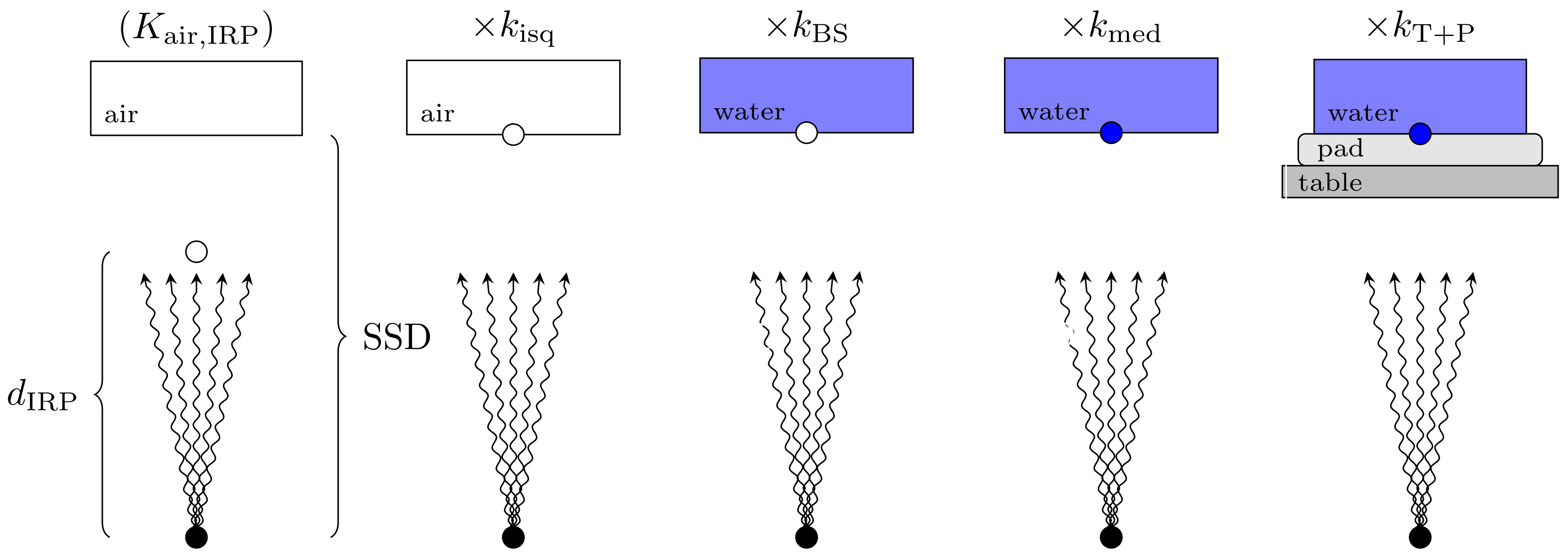

Figure 2 – The conversion from IRP air Kerma to skin dose by multiplication of the implemented correction factors. k_{isq} scales the photon fluence from IRP to the skin surface, k_{BS} corrects for backscattered photons from a Monte-Carlo simulated cuboid water phantom, k_{med} coverts air Kerma to water Kerma, and $k_{\text{T+P}}$ corrects for attenuation in the the patient support table and pad.

An ESD_{max} calculation algorithm was developed in the Python™ programming language v3.6 (Python Software Foundation), which takes RDSR as input, parses the data, and appends the above stated correction factors for each irradiation event. A database was developed for correction factor storage.

Results, discussion and future work

The ESD_{max} algorithm is presented in Figure 3, The algorithm was tested on RDSR data from two vendors and 45 different IR procedures, showing a substantial increase in the numerical of the dose metric, see Figure 4. For future development and refinement, a skin dose map should be developed for complete PSD estimations. Further, absolute dose measurements should be conducted in order to validate the reliability of the algorithm.

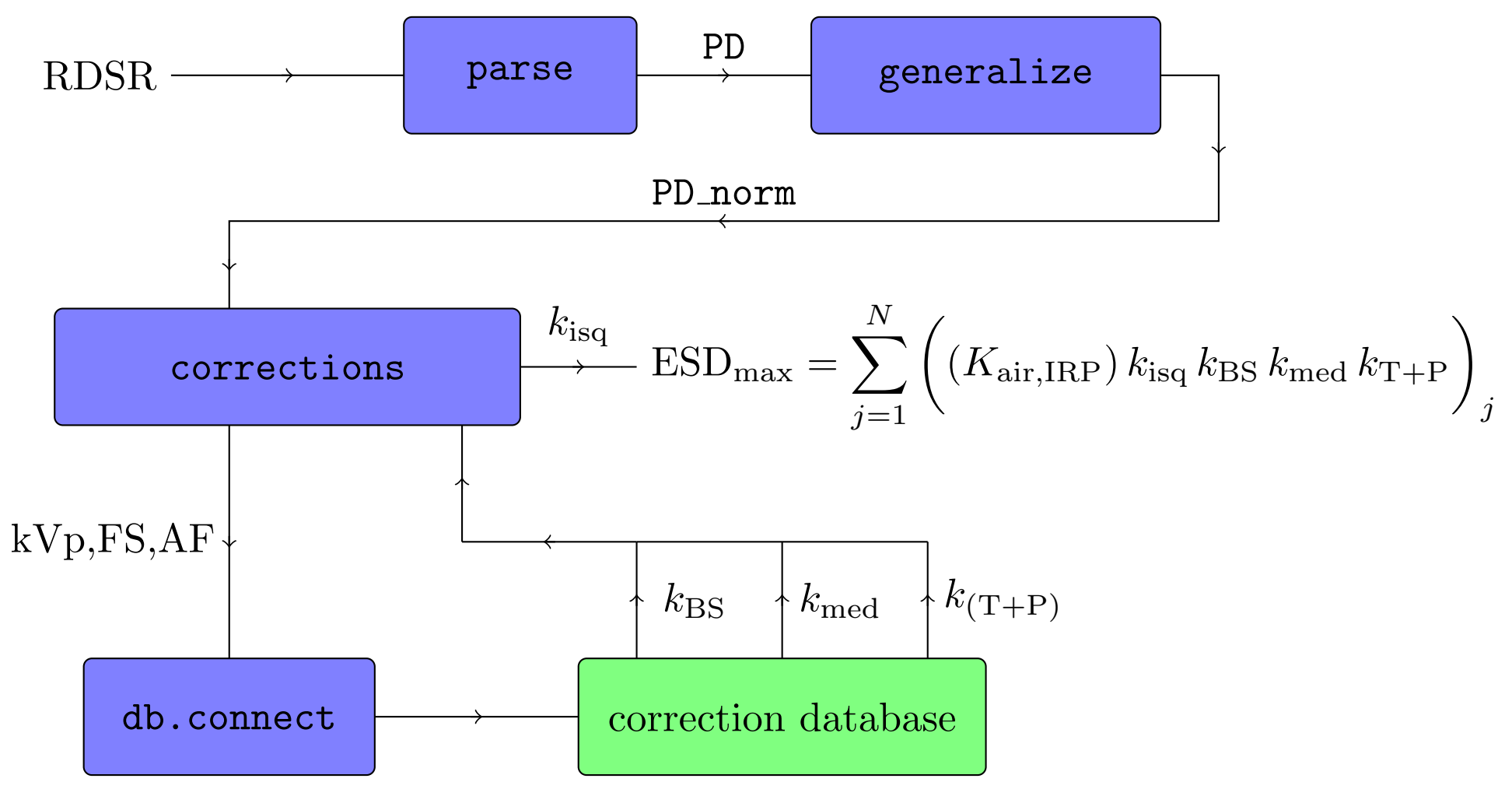

Figure 3 – System overview of the ESD_{max} algorithm. Blue boxes are Python scripts, and the green box is an SQLite database. The correction factors are obtain from irradiation event parameters such as tube voltage (kVp), field side (FS) and added beam filtration (AF).

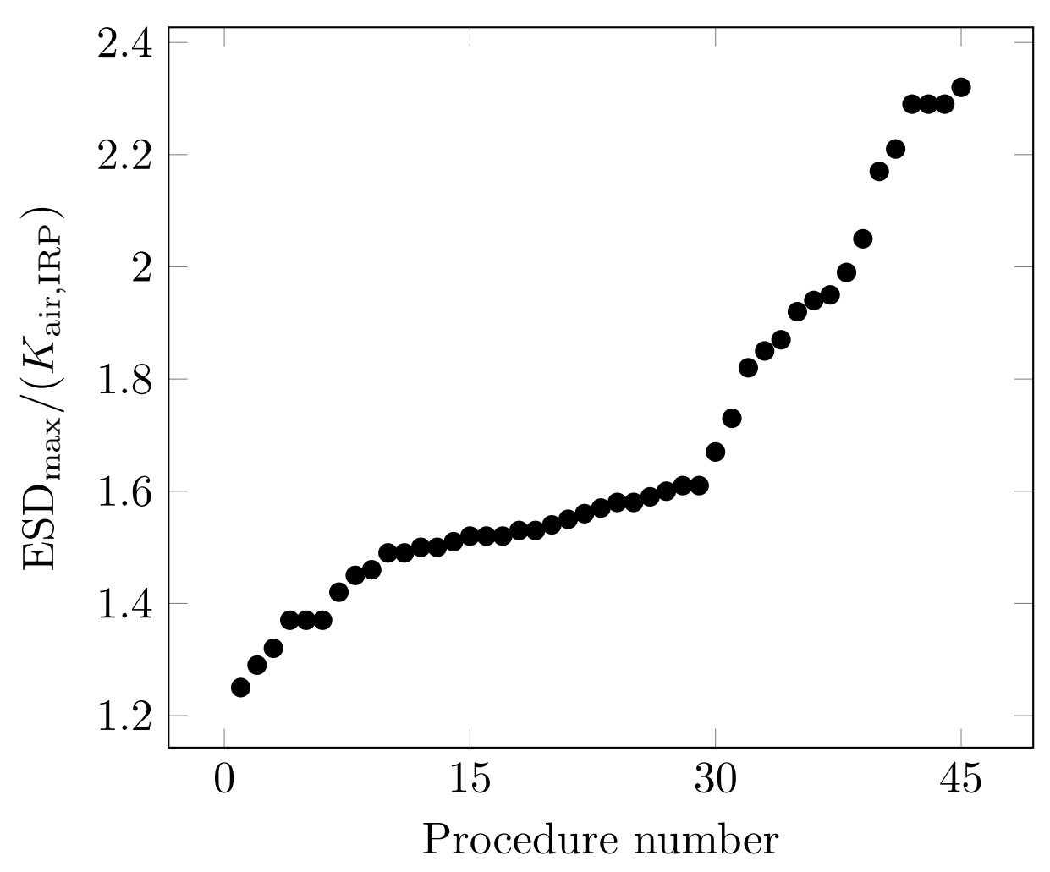

Figure 4 – ESD_{max} algorithm tested of 45 clinical procedures conducted at the University Hospital of Umeå, sorted in increasing order of the quotient.

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[1] H. Benmakhlouf, H. Bouchard, A. Fransson, and P. Andreo, "Backscatter factors and mass energy-absorption coefficient ratios for diagnostic radiology dosimetry," *Phys. Med. Biol.* 56, 7179-7204 (2011).

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