Further tweaks to Peak Skin Dose Calculation

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ABSTRACT

This study investigates correction factors commonly used in calculating peak skin dose (PSD) from IR procedures. Specifically, it examines 1- effect of patient-induced compression of the table/pad on transmission factors and, 2- the contribution of scatter from beams outside the skin patch of interest as a function of C-arm angulation. Methods: For compression effects, transmission factors of table and pad were first measured with no object on table. A 32-cm CTDI phantom was then positioned just above an ionization chamber and supported by Styrofoam blocks. Measurements were performed at various kV/filter combinations and beam angulations. The phantom was then placed directly on the table pad and measurements repeated. Additional measurements were acquired with added weight to simulate very large patients. Lateral images were used to assess compression and adjust table height to maintain the chamber at isocenter. To evaluate off-center and out-of-field dose contributions, an anthropomorphic chest phantom was used with the chamber positioned beneath it. Fluoroscopy and acquisition runs were performed at angles ranging from -60° to +60° and using multiple fields of view (FOVs). For each run, the ratio of chamber-measured air-kerma to system-displayed air kerma (C/D) was calculated. Additionally, chamber location was recorded for each view angle.
Results: Compression of the table and pad increased transmission factors (including forward-scatter) by 8% to 15%, depending on beam quality and angle of incidence. For off-center and out-of-field contributions, the normalized C/D ratio decreased to approximately 0.7 at the field edge and ranged from 0.1 to 0.4 outside the field, depending on FOV and angulation. Manual PSD calculations for several patients demonstrated that neglecting these effects could result in up to ±20% inaccuracy..
Conclusion: These findings indicate that updates to current correction factors used in PSD calculations are warranted to improve accuracy, particularly for large patients and complex geometries.

INTRODUCTION

This study investigates the correction factors typically used to calculate peak skin dose (PSD) from interventional radiology (IR) and cardiac catheterization procedures. Specifically, it examines (1) the effect of patient-induced compression of the table pad on transmission factors and (2) the contribution of scatter from beams outside the skin patch of interest as a function of C-arm angulation.

METHODS AND MATERIALS

To assess the effects of compression, the transmission factors of the table and pad were first measured with no object on the table. A 32-cm CTDI phantom was then positioned just above an ionization chamber and supported by Styrofoam blocks to ensure the pad beneath the chamber experienced no compression (Fig. 1). Measurements were performed with various kV/filter combinations, FOVs, and beam angulations. The phantom was subsequently placed directly on the table pad and measurements were repeated. Additional measurements were acquired with ~12 kg of added weight to simulate compression from a very large patient. Lateral images were used to assess pad compression and adjust table height to maintain the chamber at isocenter distance (Figures 2a & 2b). To evaluate off-center and out-of-field dose contributions, an anthropomorphic chest phantom was used with the chamber positioned beneath it. Fluoroscopy and acquisition runs were performed at angles ranging from -60° to +60° and using multiple fields of view (FOVs). For each run, the ratio of chamber-measured air-kerma to system-displayed air kerma (C/D) was calculated. Inverse-square corrections relative to 0° chamber location were also applied . Additionally, chamber location was recorded for each view angle.

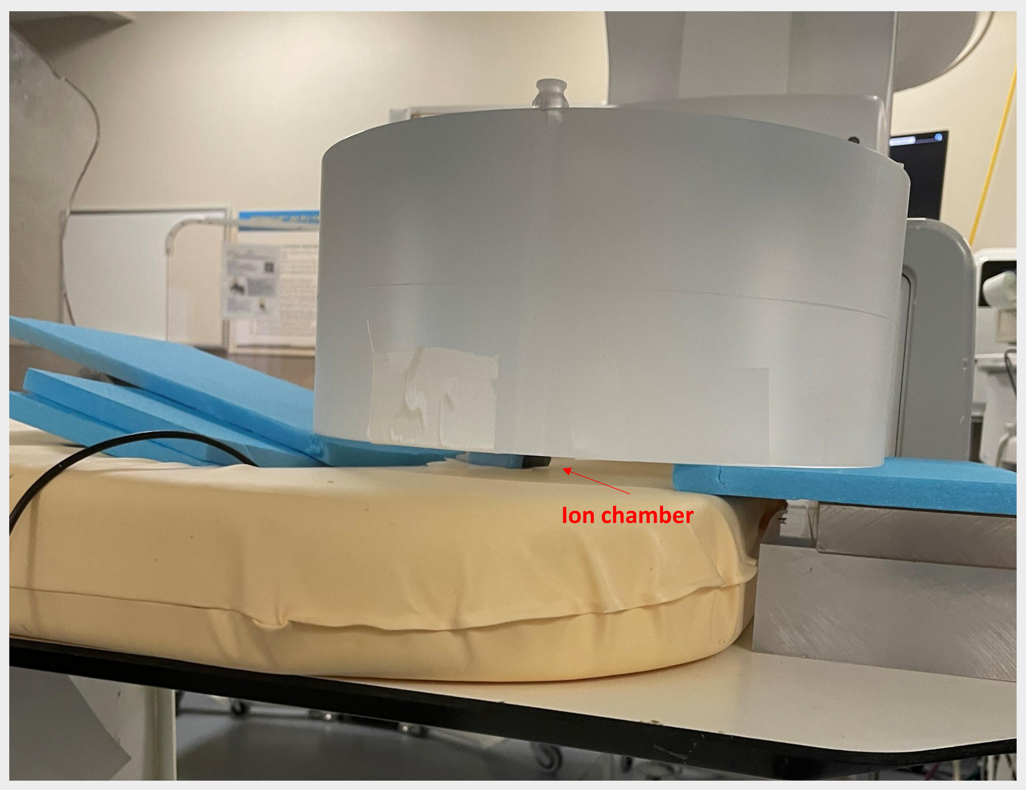

Figure 1. 32-cm CTDI phantom supported by Styrofoam blocks and just touching the ion chamber on the uncompressed pad.

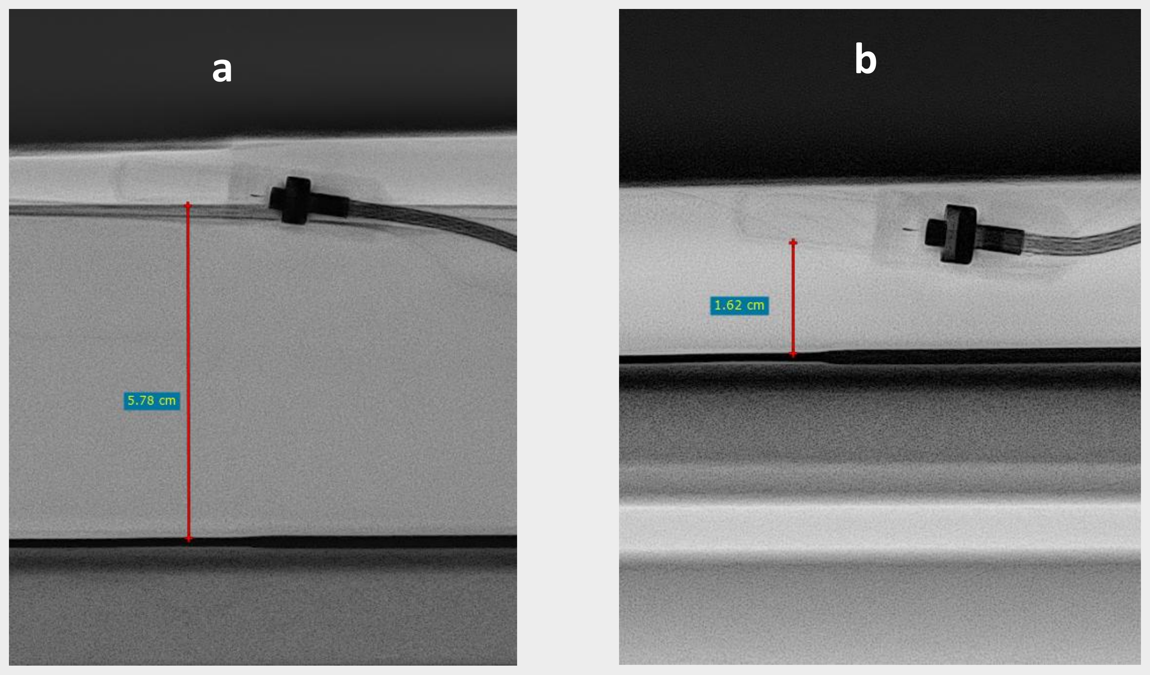

Figure 2. lateral cinegraphic images of the Farmer chamber sitting between the pad and the 32-cm CTDI phantom, with no pad compression (a) and with pad compression (b). Notice the change in thickness from 5.8cm to 1.6cm.

RESULTS

Compression of the table and pad increased transmission factors (including forward-scatter) from 6% to 15%, depending on beam quality, FOV and angle of incidence (Figure 3).

For off-center and out-of-field contributions, the normalized C/D ratio decreased to approximately 0.7 at the field edge and ranged from 0.1 to 0.4 outside the field, depending on FOV and angulation (Figure 4).

Manual PSD calculations for several patients demonstrated that neglecting these effects could result in up to ±20% inaccuracy.

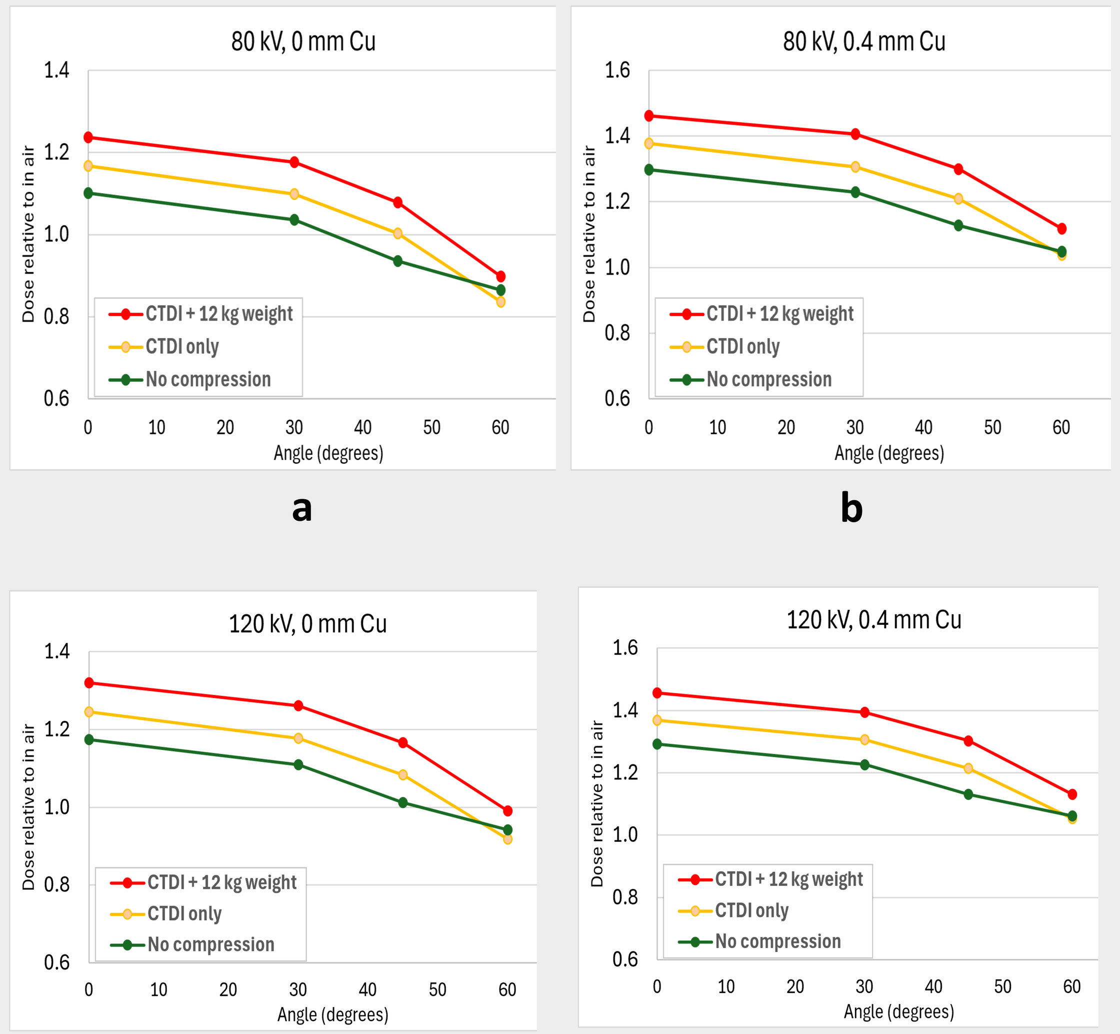

Figure 3. Effect of pad compression on entrance dose (transmission and forward scatter) with (a) 80 kV, no Cu filtration, (b) 80 kV with 0.4 mm Cu, (c) 120 kV, no Cu filtration, and (d) 120 kV with 0.4 mm Cu.

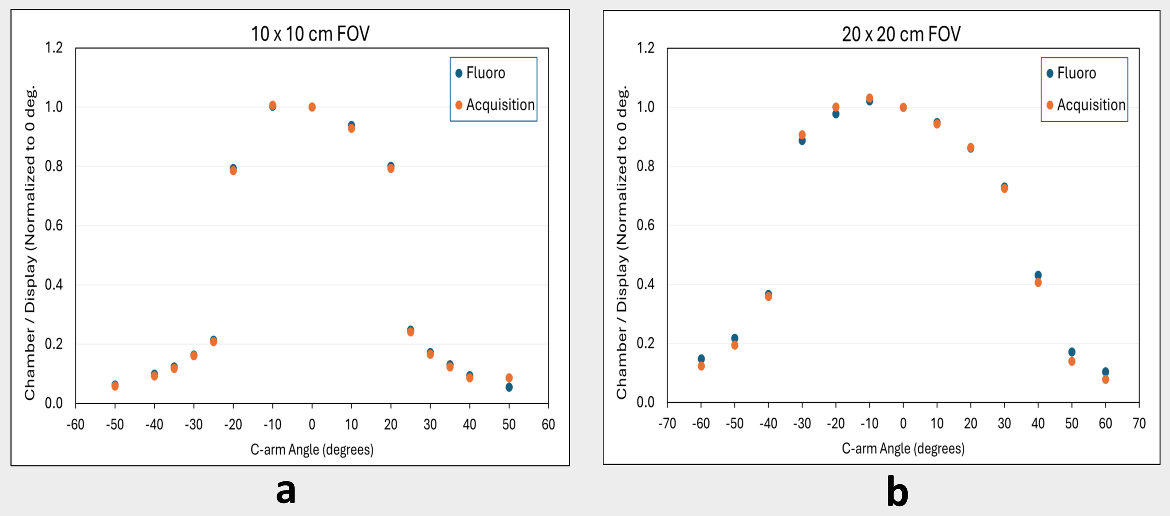

Figure 4. Dose contribution as a function of beam angle. Chamber was out of field at angles >20° and >30° for 10x10 and 20x20 FOVs, respectively. The asymmetry in doses between the -ve and +ve angles can be attributed to the heel effect and differences in backscatter from chest phantom structures at the two mirrored angles.

DISCUSSION

The phantom measurements demonstrated that table-pad compression by larger patients, if not accounted for, can result in an underestimation of PSD by as much as 15%. The magnitude of the dose increase (6–15%) depends on both patient size and FOV; larger patients and larger FOVs produce greater increases in the table-pad transmission factor (TF) and forward scatter. This relationship, however, did not appear to be influenced by either tube potential (kV) or copper filtration.

The measurements also showed that the dose contribution to a single skin location decreases rapidly to less than 70% when the C-arm is angled by approximately 20°. This reduction can be attributed to both the increased table/pad transmission factor and the inverse square law. With larger angulations, the dose contribution can decrease to >15% once the measurement point falls outside the x-ray field. The angulation at which this occurs depends on both the field size and the C-arm tilt angle.
When the table position remained unchanged, the thresholds at which the measurement point fell outside the FOV were approximately 20° and 30° for the 10 × 10 cm and 20 × 20 cm FOVs, respectively.

The difference in dose reduction between right anterior oblique (RAO) and left anterior oblique (LAO) projections was primarily attributable to the heel effect.

Overall, the uncertainty in the calculated peak skin dose was estimated to be as high as ±20%.

CONCLUSIONS

Measurements findings indicate that updates to current correction factors used in PSD calculations are warranted to improve accuracy, particularly for large patients and complex geometries.

Acknowledgments

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