Abstract

Implementation and Validation of a Software for Peak Skin Dose Calculation for a Fluoroscopy Equipment

Erica Balboni

Scuola di Specializzazione in Fisica Medica, Università degli Studi di Torino
Azienda Ospedaliero-Universitaria di Modena

Purpose: An exceeding peak skin dose (PSD) in fluoroscopy procedures is associated with deterministic effects in skin, hence its assessment is required by Italian and European law for each patient. Many commercial software perform the PSD calculus and their validation is usually performed with specific gafchromic films, which are not always available. In a recent publication the American Association of Physicists in Medicine recommended the open source software Pyskindose for the calculation of skin dose maps. In this study we aimed to implement Pyskindose for a new fluoroscopy system and to estimate the associated error for future validation of dose tracking software.

Methods and materials: The configuration required the geometric and dosimetric characterization of the system, including table displacements, beam angles, table plus pad attenuation and half value layer at different voltages. Some customizations were also introduced, including the dose calculation for Cone Beam acquisitions and the construction of computational phantoms based on patients' Computed Tomography (CT) volumes from previous radiological exams. The error associated to PSD was estimated by considering the uncertainty of the source distance, HVL, table and pad attenuation and field homogeneity. In absence of suitable gafchromic films, the ones usually employed in radiotherapy were calibrated and irradiated with 4 simple exposure sequences as an additional test for previous assessments. The software was applied on 16 performed procedures and the PSD when using custom and standard phantoms were compared to the total Kerma at reference point.

Results: The estimated error of Pyskindose, to be considered when using the CT custom phantoms, was of 9%, which is comparable to the documented uncertainty associated to gafchromic films for fluoroscopy. This result could not be reproduced by the used gafchromic films, whose uncertainty was of 15%. However, the experimental maps reflected what was previously found with RDSR evaluation, i.e. differences inferior to 0.5cm in table displacements and beam collimation. The highest average dose difference in the considered regions of interest was of 19%. The maximum

observed discrepancy for the use of the standard phantom instead of the custom one was of 20%, observed in patients with large body size and angled procedures; while the total Kerma at reference point differed from PSD of at most 35% for procedures performed at a nearer distance from the source.

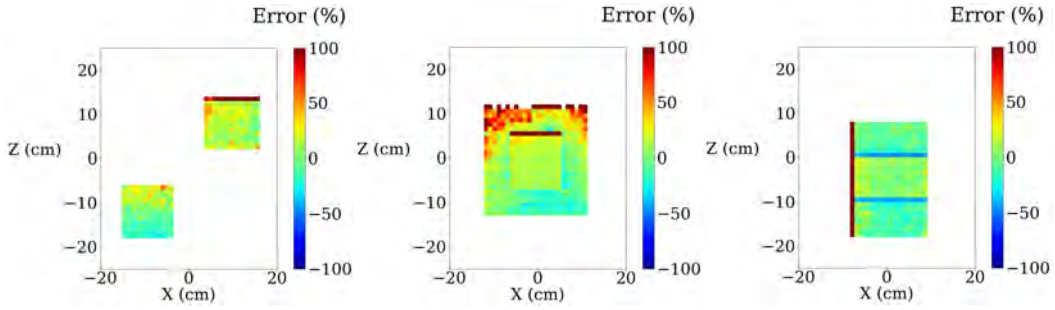

Figure 1: Difference maps between gafchromic films and Pyskindose software.

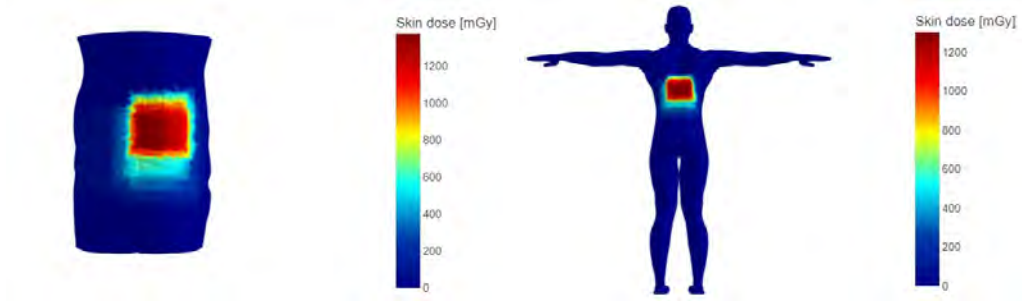

Figure 2: Skin dose maps using CT phantom (on the left) and the standard Pyskindose phantom (on the right).

Conclusion: Pyskindose was deemed accurate enough to perform the validation of new dose tracking software and to be employed in critical cases to increase the quality of the evaluation.

References

[1] AIFM. (2019). Associazione Italiana di Fisica Medica. Report 14 - Linee guida per i controlli di qualità in angiografia digitale con rivelatore a flat panel.

[2] Andersson, J., Bednarek, D. R., Bolch, W., Boltz, T., Bosmans, H., Gislason-Lee, A. J., . . . Zamora, D. (2021). Estimation of patient skin dose in fluoroscopy: summary of a joint report by AAPM TG357 and EFOMP. Medical Physics, 48 (7), e671–e696. doi:https://doi.org/10.1002/mp.14910. eprint: https://aapm.onlinelibrary.wiley.com/doi/pdf/10.1002/mp.14910

[3] Balter, S., Hopewell, J. W., Miller, D. L., Wagner, L. K., & Zelefsky, M. J. (2010). Fluoroscopically guided interventional procedures: A review of radiation effects on patients' skin and hair. Radiology, 254 2, 326–41. Retrieved from https://api.semanticscholar. org/CorpusID:11013431

[4] Benmakhlouf, H., Fransson, A., & Andreo, P. (2012). Influence of phantom thickness and material on the backscatter factors for diagnostic x-ray beam dosimetry. Physics in Medicine & Biology, 58 (2), 247. doi:10.1088/0031-9155/58/2/247

[5] Chen, D. T. (2023). Dicom2stl. https://github.com/dave3d/dicom2stl. GitHub. Colombo, P. E., Rottoli, F., Felisi, M., De Mattia, C., Riga, S., Sutto, M., . . . Torresin, A. (2020). Validation of a dose tracking software for skin dose map calculation in interventional radiology. Physica Medica, 72, 122–132. doi:https://doi.org/10.1016/ j.ejmp.2020.03.008

[6] Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom. :73.

[7] Decreto Legge 31 luglio 2020 N. 101. Attuazione della direttiva 2013/59/EURATOM che stabilisce norme fondamentali di sicurezza relative alla protezione contro i pericoli derivanti dall'esposizione alle radiazioni ionizzanti, e che abroga le direttive 89/618/EURATOM, 90/641/EURATOM, 96/29/EURATOM, 97/43/EURATOM e 2003/122/EURATOM, e riordino della normativa di settore in attuazione dell'articolo 20, comma 1, lettera a), della Legge 4 ottobre 2019, n. 117. Pubblicato nella Gazzetta Ufficiale n. 201 del 12 agosto 2020 - Supplemento Ordinario n. 29.

[8] delle Canne, S., Carosi, A., Bufacchi, A., Malatesta, T., Capperella, R., Fragomeni, R., . . . Begnozzi, L. (2006). Use of gafchromic xr type r films for skin-dose measurements in interventional radiology: Validation of a dosimetric procedure on a sample of patients undergone interventional cardiology. Physica Medica, 22 (3), 105–110. doi:https:// doi.org/10.1016/S1120-1797(06)80004-9

[9] Greffier, J., Van Ngoc Ty, C., Bonniaud, G., Moliner, G., Ledermann, B., Schmutz, L., . . . Pereira, F. (2017). Assessment of peak skin dose in interventional cardiology: A comparison between gafchromic film and dosimetric software em.dose. Physica Medica, 38, 16–22. doi:https://doi.org/10.1016/j.ejmp.2017.05.044

[10] Hellstr¨om, M., Granberg, C., Lundman, J., Riklund, K., & Andersson, J. (2020). Introducing PySkinDose, a novel framework for patient peak skin dose estimation in interventional radiology. doi:10.26044/esi2020/ESI-00814

[11] ICRP. (2007). Radiological Protection in Medicine. ICRP Publication 105. Ann. ICRP, 37 (6).

[12] ICRP. (2012). ICRP Statement on Tissue Reactions / Early and Late Effects of Radiation in Normal Tissues and Organs – Threshold Doses for Tissue Reactions in a Radiation Protection Context. ICRP Publication 118. Ann. ICRP, 41 (1/2).

[13] ICRP. (2013). Radiological protection in cardiology. ICRP Publication 120. Ann. ICRP, 42 (1).

[14] ICRP. (2018). Occupational radiological protection in interventional procedures. ICRP Publication 139. Ann. ICRP, 47 (2).

[15] IEC. (2011). International Electrotechnical Commission IEC 60601-2-63 Ed.1: Medical electrical equipment - Part 2-63: Particular requirements for basic safety and essential performance of dental extra-oral X-ray equipment.

[16] Jones, A. K., Ensor, J. E., & Pasciak, A. S. (2014). How accurately can the peak skin dose in fluoroscopy be determined using indirect dose metrics? Medical Physics, 41 (7), 071913. doi:https://doi.org/10.1118/1.4884020

[17] Jones, A. K., & Pasciak, A. S. (2011). Calculating the peak skin dose resulting from fluoroscopically guided interventions. Part I: Methods. Journal of Applied Clinical Medical Physics, 12 (4), 231–244. doi:https://doi.org/10.1120/ jacmp.v12i4.3670.

[18] Lin, P.-J. P., Goode, A. R., Corwin, F. D., Fisher, R. F., Balter, S., Wunderle, K. A., . . . Gonzalez, S. (2022). AAPM Task Group Report 272: Comprehensive acceptance testing and evaluation of fluoroscopy imaging systems. Medical Physics, 49 (4), e1– e49. doi:https://doi.org/10.1002/mp.15429

[19] Mehranian, A., Ay, M. R., Alam, N. R., & Zaidi, H. (2010). Quantifying the effect of anode surface roughness on diagnostic x-ray spectra using monte carlo simulation. Medical Physics, 37 (2), 742–752. doi:https://doi.org/10.1118/1.3284212

[20] Philips Medical Systems. (2017). DICOM Conformance Statement. Azurion R1.2. Philips Medical Systems. (2020). Azurion Versione 2.1 Istruzioni per l'uso.

[21] Rehani, M. M., Miller, D. L., & Baliyan, V. (2021). High-Dose Fluoroscopically Guided Procedures in Patients: Radiation Management Recommendations for Interventionalists. Cardiovasc Intervent Radiol ., 44 (6), 849–856. doi:https://doi.org/10.1007/ s00270-020-02703-2