Should we consider treatment machine uncertainties in radiotherapy planning?

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Purpose

Dose given by the treatment planning system(TPS) reflects an ideal situation as we classically assume the patient as a rigid object and delivery uncertainties from the treatment machine are not present. For the uncertainties related to the patient, different strategies (image guidance, motion/setup uncertainty simulation) have found the way to TPSs (Lit 1-3). From there we asked if and how typical machine delivery errors like gantry and MLC positions, isocenter and gantry sag uncertainties will have an effect on the dose distribution or if they can be neglected within the radiotherapy process.

Methods

Main delivery errors like gantry sag (2mm), isocenter uncertainty (2mm), MLC calibration errors (+/-2mm) and gantry angle errors (+/- 2°) are tested for 3 patient cases (Prostate, BC, H+N). Modified DICOM RT plan files generated with an IDL (Harris Geospatial Solutions) tool are reimported into and recalculated in Raystation 8.0 (Raysearch). For evaluation the volume dose factor was calculated by multiplying each DVH dose point and volume. To compare this factor we also derived for different dose prescriptions (+/- 2Gy). From that, we were able to state a dose offset on total dose, the error introduced was equivalent with (Fig. 1).

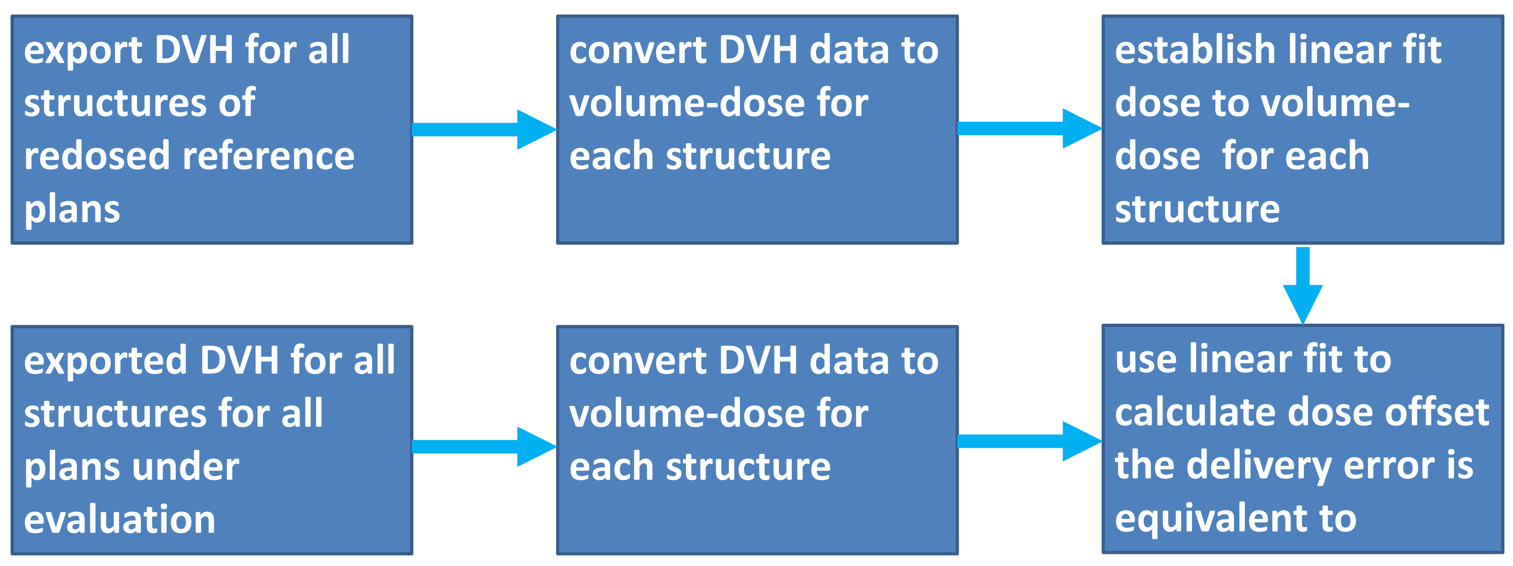

Fig. 1: Method to find a comparable dose offset on total dose.

Results

Results gave complex dependencies for the different volumes and cases (Fig. 2-5):

Gantry sag: Prostate and BC had higher doses for higher sag for all volumes while H+N had lower doses at targets only.

Isocenter: H+N and BC had lower doses for all volumes while prostate only some had higher doses.

MLC calibration: clear correlation- larger field is more dose.

Gantry angle: H+N and BC mostly had lower and prostate had some higher doses.

In general the errors resulted in a higher dose offset when volumes were small (H+N case).

Conclusion

Common delivery errors do vary the dose more than expected but the dose change is difficult to predict as it depends on the case and beam arrangement. Therefore new dose calculation models should include a kind of dose uncertainty display based on general or even better individual machine QA results.

Literature

<1> Verellen, D., De Ridder, M., Linthout, N., Tournel, K., Soete, G., & Storme, G. (2007). Innovations in image-guided radiotherapy. *Nature Reviews Cancer*, *7*(12), 949.

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<3> Nijkamp, J., Pos, F. J., Nuver, T. T., De Jong, R., Remeijer, P., Sonke, J. J., & Lebesque, J. V. (2008). Adaptive radiotherapy for prostate cancer using kilovoltage cone-beam computed tomography: first clinical results. *International Journal of Radiation Oncology* Biology* Physics*, *70*(1), 75-82.

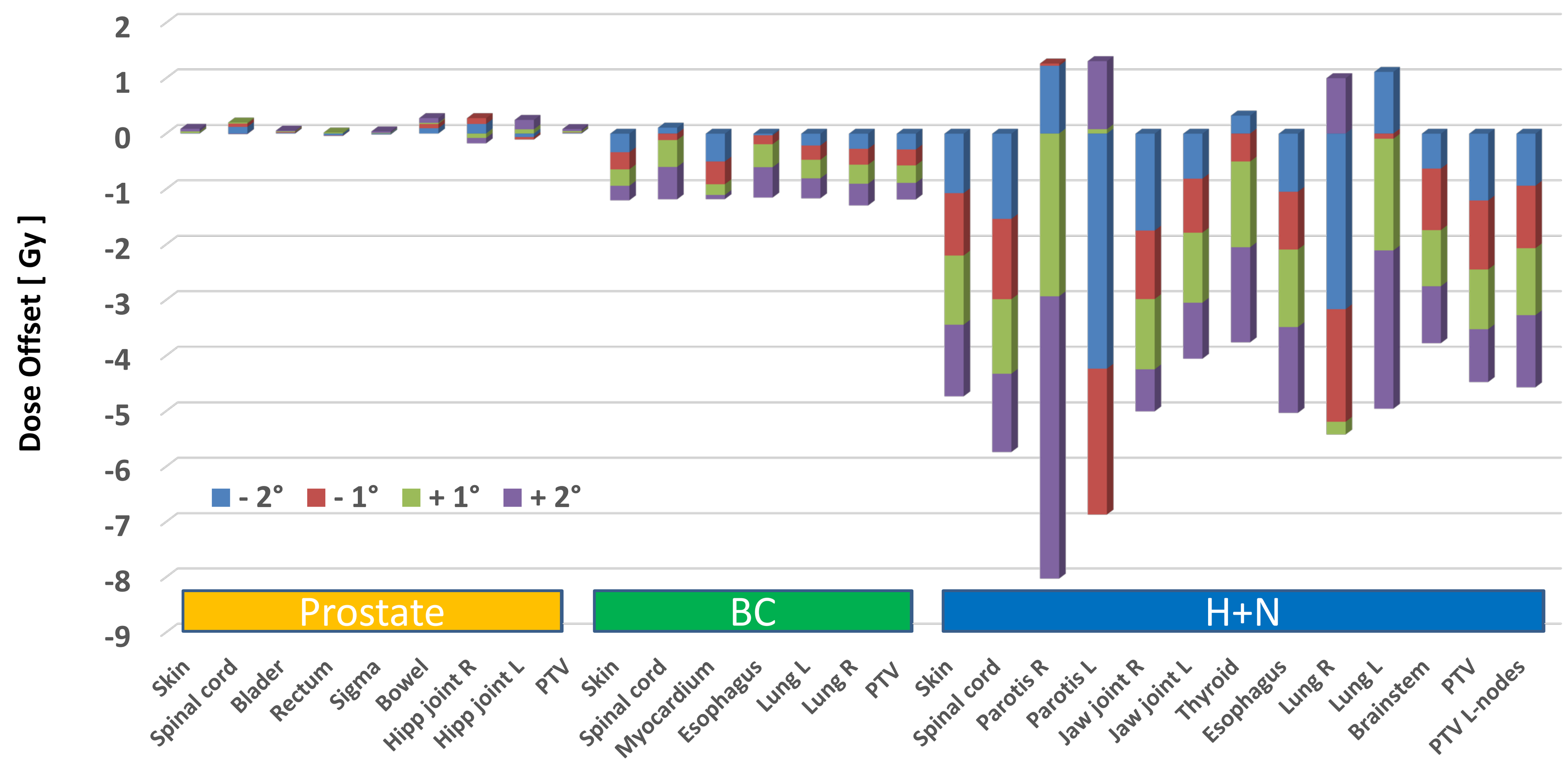

Fig. 2: Resulting dose offset on misalignment of Gantry angle for 3 cases.

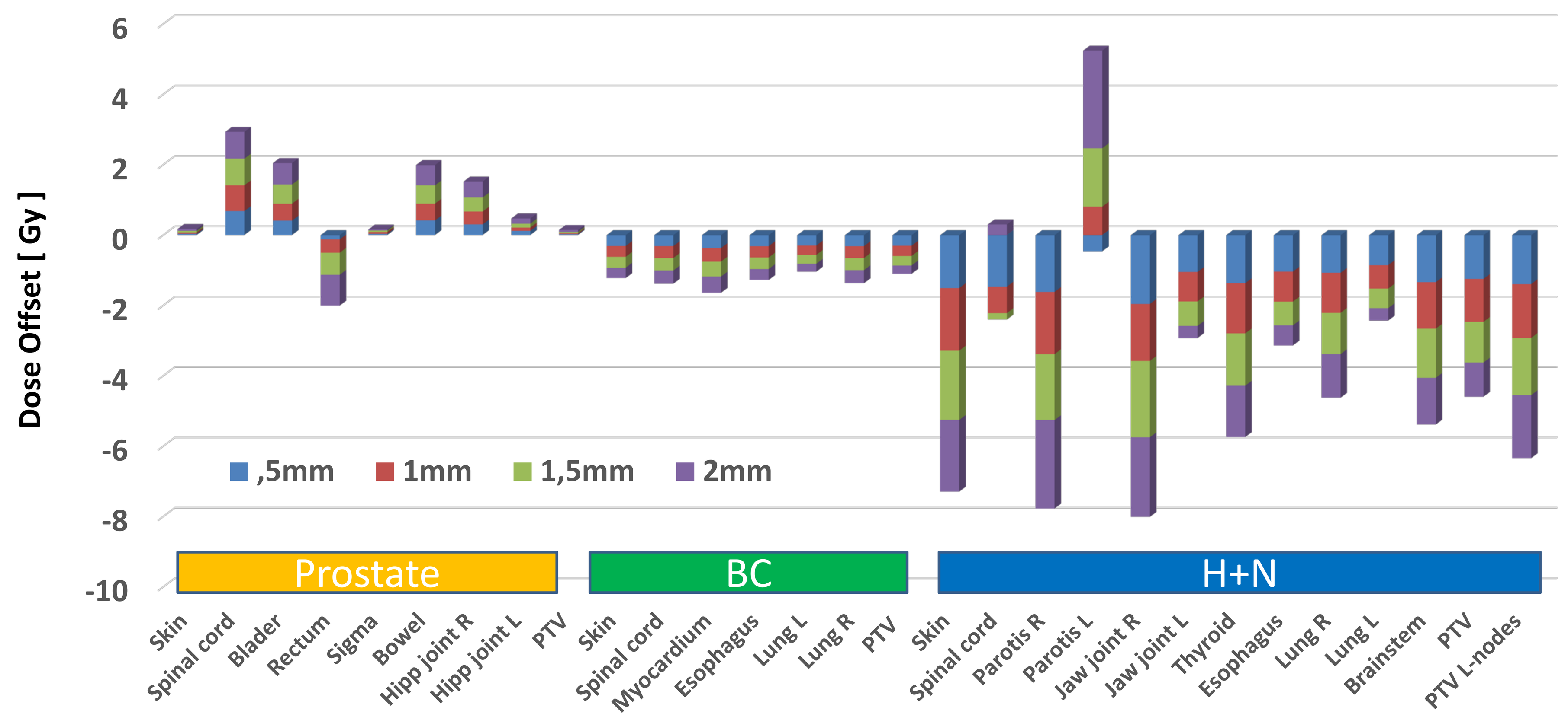

Fig. 3: Resulting dose offset on isocenter spot size.

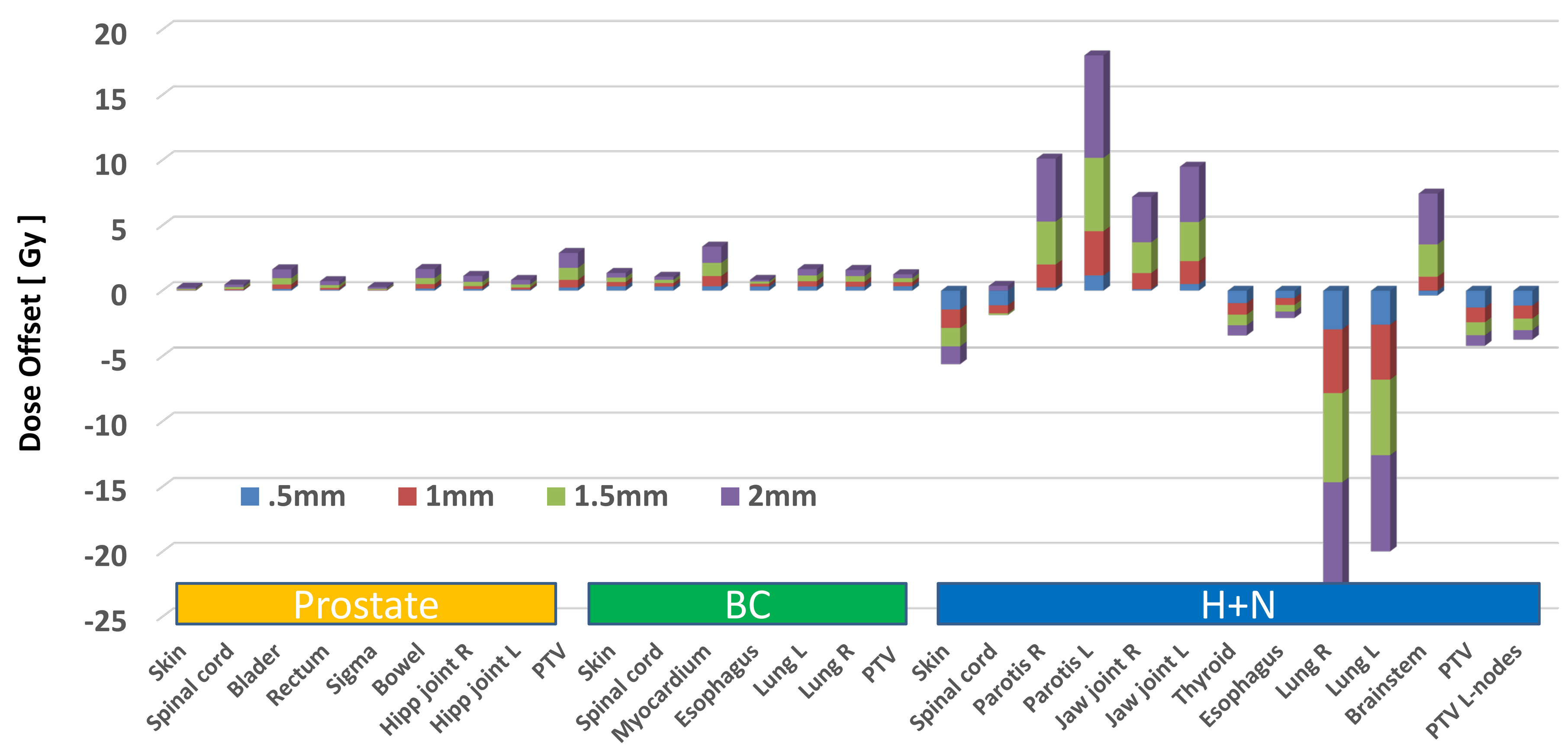

Fig. 4: Resulting dose offset on gantry sagg.

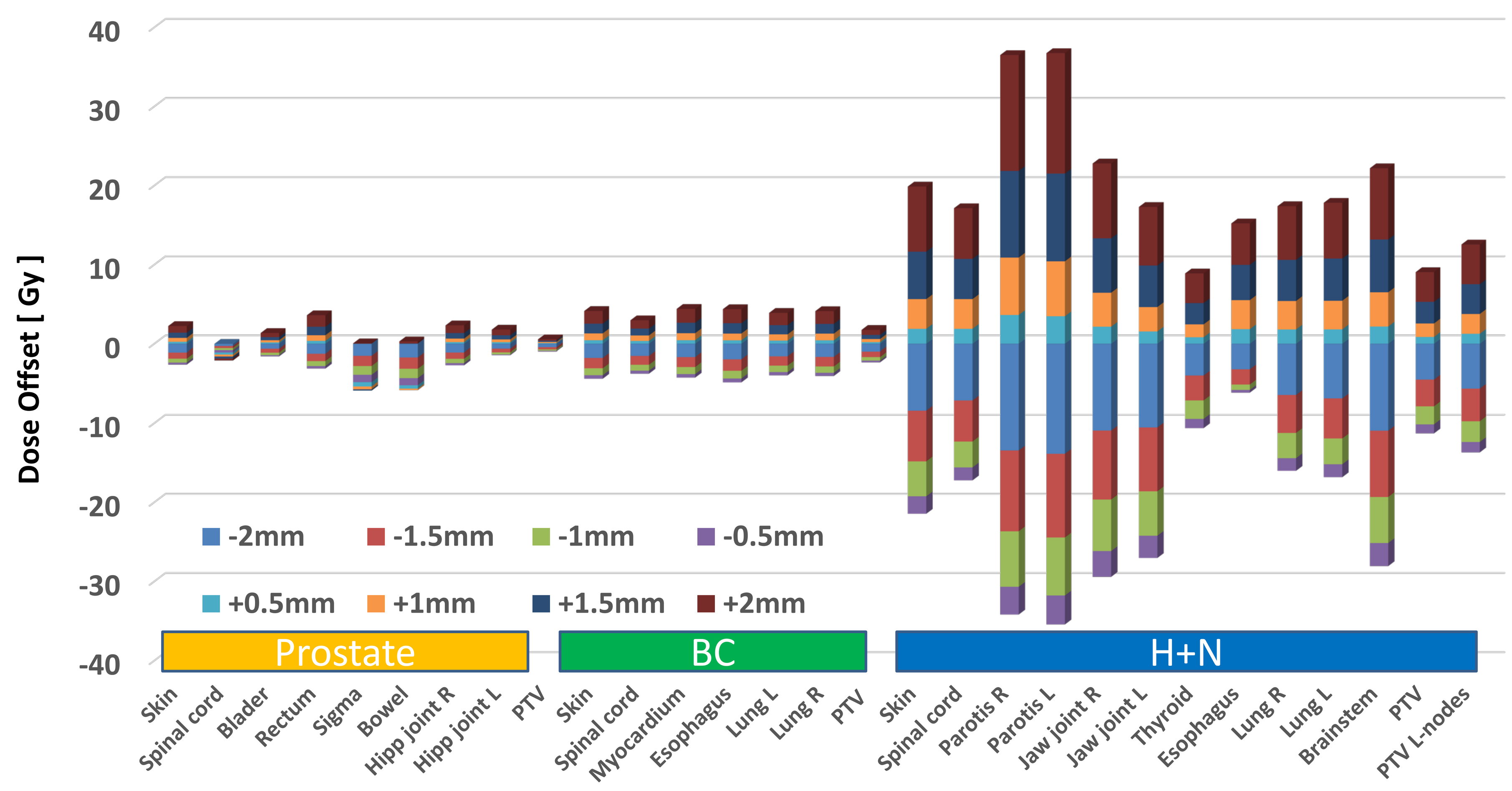

Fig. 5: Resulting dose offset on MLC field size calibration error.