MICRO-RAYSTATION IN PRE-CLINICAL RESEARCH

μ-RayStation* is a software platform for planning and evaluation in small animal irradiation research. μ-RayStation combines the power of RayStation for patient modelling, visualization and general workflow with the accuracy of Monte Carlo (MC) dose calculation. Special machine models for small animal irradiation research platforms have been developed for μ-RayStation, enabling treatment planning with various X-ray irradiators.

THE μ-RAYSTATION PLATFORM

μ-RayStation is based on the clinical treatment planning system (TPS) RayStation 5, and most of the standard functionality is retained. However, a series of adaptations to facilitate its use for small animal irradiation research have been done; first, smaller voxels for specimen modelling and dose computations (down to 0.1 mm) are allowed, and second, μ-RayStation uses new machine models and a MC dose engine validated for small animal irradiation research. μ-RayStation inherits the powerful Python scripting framework from RayStation 5 (for automating and extending functionality) and plan evaluation tools (plan comparison, dose summation, dose statistics, etc.). With all this, μ-RayStation enables a fast and straightforward workflow, with accurate specimen modeling and dose calculation, for kilovoltage X-ray irradiation of small animals.

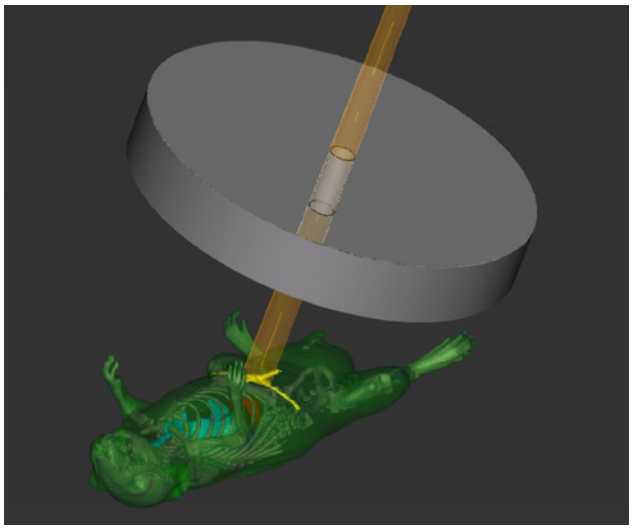

Figure 1. *A 3D rendering of a segmented whole-body mouse image, including the geometry of a circular cone beam.*

CONTOURING AND IMAGE REGISTRATION

μ-RayStation supports various manual, semi-manual and automatic contouring tools, e.g. region growing, smart brushes, thresholding and contour algebras, greatly simplifying specimen segmentation. The same image registration functionality present in RayStation 5, i.e. rigid and deformable, is retained in μ-RayStation, enabling summation of deformed doses.

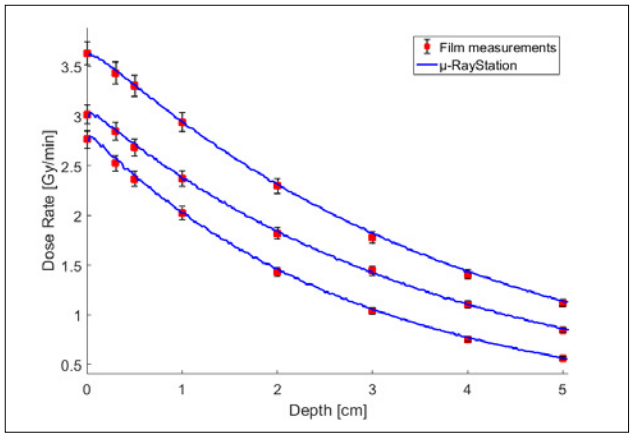

Figure 2. *Film depth dose measurements with corresponding μ-RayStation dose, for collimation diameters of 1, 2.5 and 5 mm. The mean difference ($(D_{\mu RS} - D_{film}) / D_{film}$) are 1.2, 1.0 and 1.1 %, for 1, 2.5 and 5 mm collimation, respectively. The error bars display the uncertainty in the film measurements (3.2 %). The μ-RayStation dose calculation grid size is 0.2 mm and the dose uncertainty is roughly 0.5 %.*

PLANNING AND DOSE CALCULATIONS

Two irradiation techniques are supported in μ-RayStation: 3D-CRT and static arc. 3D-CRT plans comprise of one or more beams with fixed angles and collimation for each beam (visualization of a beam can be seen in Figure 1. An example of a 3D-CRT treatment plan dose is displayed in Figure 4). Static arc plans comprise of one or more arc beams with fixed collimation and user specified start and stop gantry angles.

The dose calculations in μ-RayStation are performed with the use of the MC code VMC++ [1]. To achieve the highest precision, the transport energy thresholds (AP, AE, Ecut) are set to 10 keV. The user can select the number of histories per mm^2, and whether to report dose-to-water or dose-to-medium.

* μ-RayStation is intended for pre-clinical research (in accordance with guidelines for ethical use of animals in research), and is not to be used for any clinical purpose.

MACHINE MODELING

µ-RayStation supports small animal X-ray irradiation systems with field aperture specified by fixed shape exit collimator, like the cones in e.g. the X-RAD 225Cx system. The analytical machine model is used to sample photon sets (position, direction and energy when exiting the irradiator), that are used by the dose engine in the dose calculation. The machine model consists of three basic components; a kilovoltage X-ray source, an optional fixed entrance collimator (closest to the source) and an exit collimator.

DOSE CALCULATION VALIDATION

The µ-RayStation dose calculation has been validated through comparison with measurements and calculations by the EGSnrc MC code, which was considered a golden benchmark reference.

An extensive comparison between VMC++ and EGSnrc was performed to fully validate the performance of VMC++ for small voxels (0.1 mm) and kilovoltage energy spectra. Overall, a VMC++ vs. EGSnrc agreement within 1% of dose maximum was demonstrated for a typical X-ray tube energy spectrum (200 kV), and the results for single energies are in line with what have been reported for larger voxel sizes by Terribilini et al [2].

To evaluate the complete system, and therefore also the modeling of the machine, dose computations for the X-RAD 225Cx system have been validated at Institut Cancérologie de l'Ouest (Nantes, France, measurement data from [3]). Measured film depth doses in water display a mean agreement of around 1%, see Figure 2. Corresponding profile measurements can be seen in Figure 3.

CONCLUSIONS AND OUTLOOK

All in all, µ-RayStation is a TPS suited for pre-clinical small animal irradiation research. It offers fast and easy treatment planning and evaluation, with accurate dose computation and advanced functionalities. The system will continue to evolve to meet the needs in the field of small animal irradiation research, and to support proton, and heavier ions, irradiators using the proton MC dose engine implemented in RayStation, which will also provide distributions of LET/RBE and other related quantities.

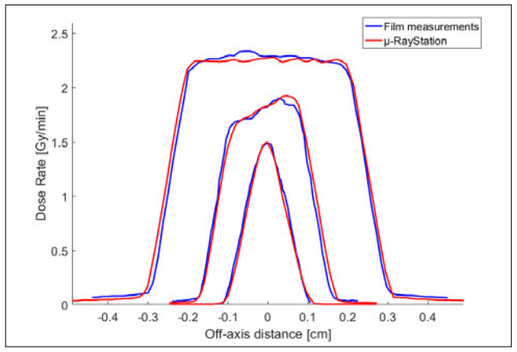

Figure 3. *Film profile dose measurements with the corresponding µ-RayStation dose for collimation diameters of 1, 2.5 and 5 mm. All profiles are at a depth of 2 cm.*

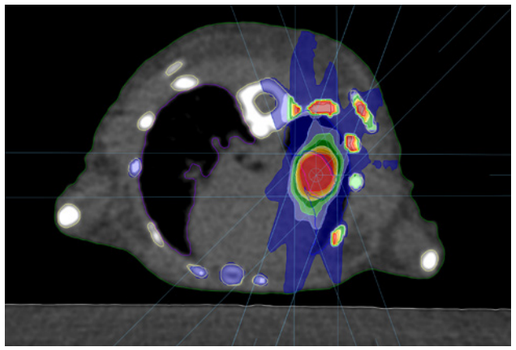

Figure 4. *An example of a 3D-CRT mouse lung treatment plan consisting of 5 beams (image and plan from Institut Cancérologie de l'Ouest in Nantes, France). The dose calculation grid size is 0.2 mm and the dose uncertainty is roughly 0.5 % for each beam.*

"µ-RayStation is a complete, powerful and user-friendly treatment planning system dedicated to pre-clinical irradiators. A large set of relevant clinical tools are available in µ-RayStation, allowing a fast and efficient treatment planning for small animals."

Sophie Chiavassa, *Medical physicist,*
Institut de Cancérologie de l'Ouest ICO – Nantes

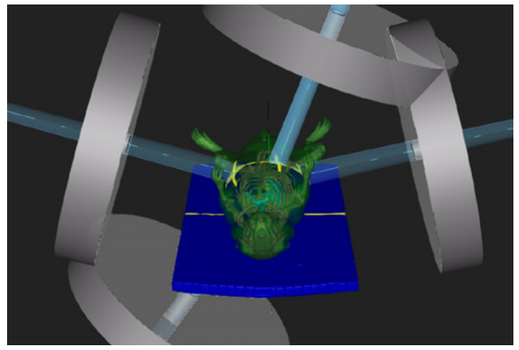

Figure 5. *A visualization of a 3D-CRT plan consisting of four beams.*

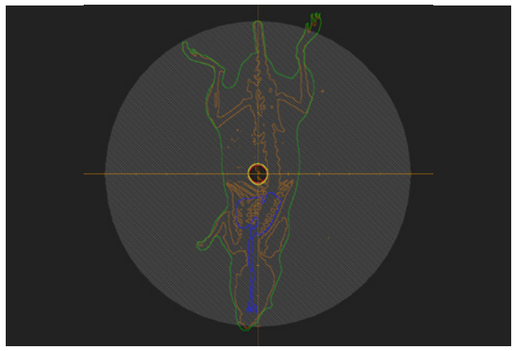

Figure 6. *Beams eye view of one of the beams from Figure 5.*

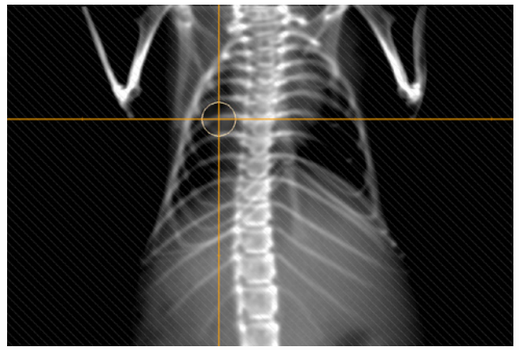

Figure 7. *A digitally reconstructed radiograph for one of the beams on Figure 4.*

REFERENCES

[1] Iwan Kawrakow, Matthias Fippel. Vmc++. A fast mc algorithm for radiation treatment planning. The Use of Computers in Radiation Therapy, p. 126-128, Springer, 2000.
[2] Dario Terribilini, Michael K Fix, Daniel Frei, Werner Volken, and Peter Manser. Vmc++ validation for photon beams in the energy range of 20-1000 keV. Medical physics, 37(10):5218-5227, 2010.
[3] Caroline Noblet, Sophie Chiavassa, F Smekens, David Sarrut, V Passal, J Suhard, Albert Lisbona, Francois Paris, and Gregory Delpon. Validation of fast monte carlo dose calculation in small animal radiotherapy with ebt3 radiochromic films. Physics in medicine and biology, 61(9):3521, 2016.

For more information or to book a demo,
visit www.raysearchlabs.com

RaySearch Laboratories

μ-RayStation Version: 2018-03-06