µ-RayStation

µ-RayStation: PLANNING FOR 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 and speed of GPU accelerated Monte Carlo (MC) dose calculation specifically tailored for small animal irradiation. The system supports modelling of various small animal X-ray irradiators, enabling fast and accurate planning of small animal precision irradiation research.

THE µ-RAYSTATION PLATFORM

µ-RayStation is based on the clinical treatment planning system (TPS) RayStation, and most of the standard functionality is retained. However, a series of adaptations to facilitate its use for small animal irradiation research have been implemented; first, tools for contouring, registrations and visualizations have been adapted to work for small objects, second, the µ-RayStation dose engine has been adapted to be accurate for low energies and small dose grid voxels, third, a new machine model suitable for small animal irradiators is introduced. µ-RayStation inherits the powerful Python scripting framework from RayStation (for automating and extending functionality) and plan evaluation tools (plan comparison, dose summation, dose statistics, robust evaluation 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.

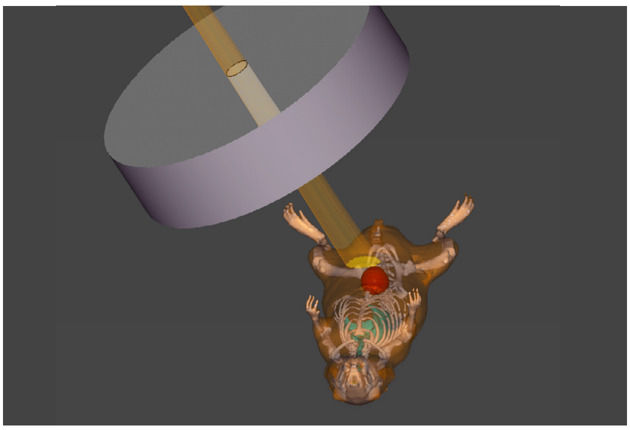

Figure 1. *A 3D rendering of a segmented whole-body mouse image, including the geometry of a circular fixed collimator beam.*

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, i.e. rigid and deformable, is retained in µ-RayStation, enabling, e.g., contour propagation and summation of deformed doses.

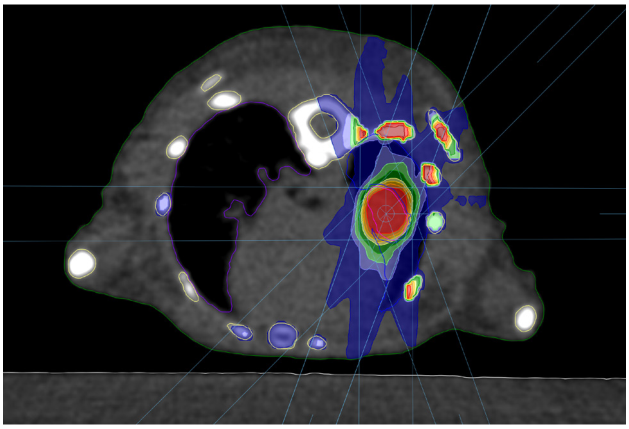

Figure 2. *An example of a 3D-CRT mouse lung treatment plan consisting of 5 beams (image and plan from Institut Cancérologie de l'Ouest in Nantes, France). The dose calculation grid size is 0.2 mm and the dose uncertainty is roughly 0.5 %.*

PLANNING AND DOSE CALCULATIONS

µ-RayStation supports planning with both static and arc beams, either with fixed collimators or jaw-like collimators. In Figure 1, a static beam with a circular fixed collimator can be seen. In Figure 2, the dose for a five field plan can be seen.

The dose calculations in µ-RayStation are performed with the use of the RayStation photon GPU MC [1]. To achieve the highest precision, various adaptations to model low energies more accurately have been made from the clinical code. The user can select the requested statistical uncertainty in percent, 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 consisting of an X-ray tube and sets of fixed (or rectangularly variable) collimators, like the SARRP and SmART+ systems. The analytical machine model is used to sample photons (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, see Figure 4.

DOSE CALCULATION VALIDATION

The µ-RayStation dose calculation has been validated through comparison with both measurements and external MC calculations.

An extensive comparison between the RayStation GPU MC and EGSnrc was performed to fully validate the performance of the GPU MC for small voxels (0.1 mm) and kilovoltage energy spectra. Overall, an 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 the VMC++ code by Terribilini et al [2].

To evaluate the complete system, and therefore also the modeling of the machine, dose calculations for the X-RAD 225Cx system have been validated at Institut Cancérologie de l'Ouest (Nantes, France, equivalent to the study in [3] but with the RayStation GPU MC) [4]. Measured film depth doses in water display a mean agreement of around 1%, see Figure 3. Corresponding profile measurements can be seen in the figure.

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 calculation 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.

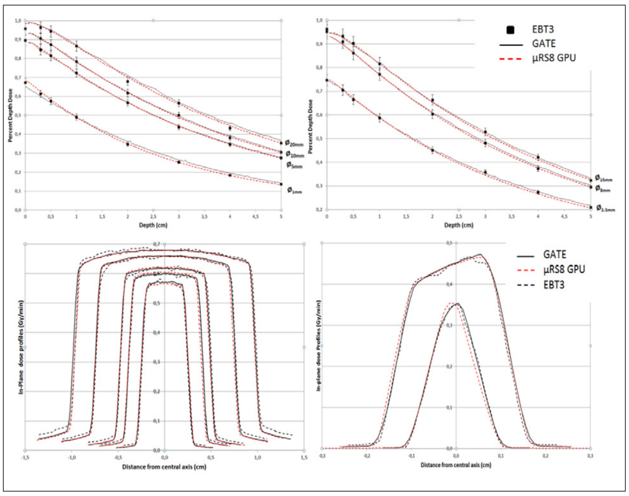

Figure 3. *Film dose measurements with corresponding µ-RayStation dose (and external independent GATE simulations of the full irradiator [3]), for various fixed collimators. On the top row, depth doses are displayed, the mean difference ((DµRS - Dfilm) /Dfilm) is 1.2%, 0.9%, 0.8%, 0.8%, 0.5%, 0.6% and 0.9% for collimators with a field diameter of 20, 15, 10, 8, 5, 2.5 and 1 mm, respectively (global mean error 0.8%). The error bars display the uncertainty in the film measurements (3.2 %). On the bottom row, dose profile are shown with diameters of 5, 8, 10, 15 and 20 mm to the left and 2.5 and 1 mm to the right.*

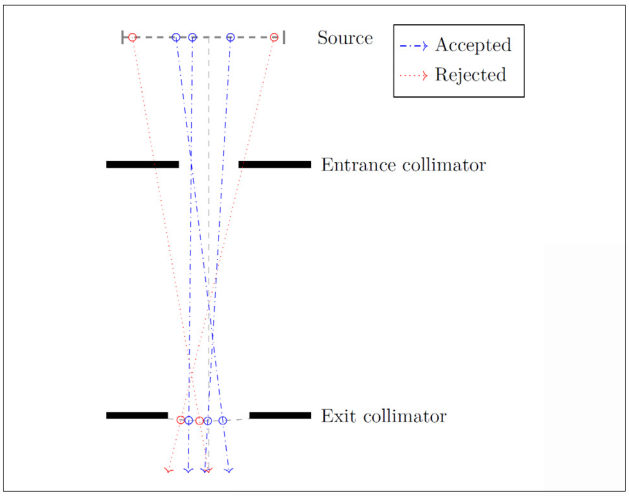

Figure 4. *Schematic view of the irradiator machine model, consisting of a source, entrance collimator and exit collimator. The generic nature of these components means that many different systems can be modeled. Based on the position and size of the different components, photons can be sampled for the dose calculation.*

"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

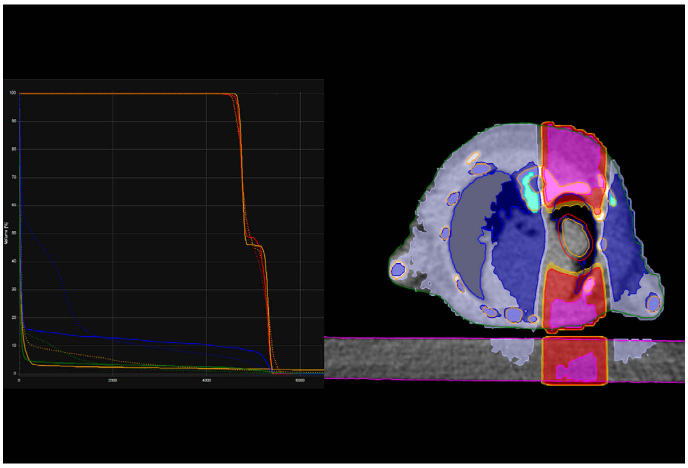

Figure 5. *Comparing two plans using the DVH and dose difference views.*

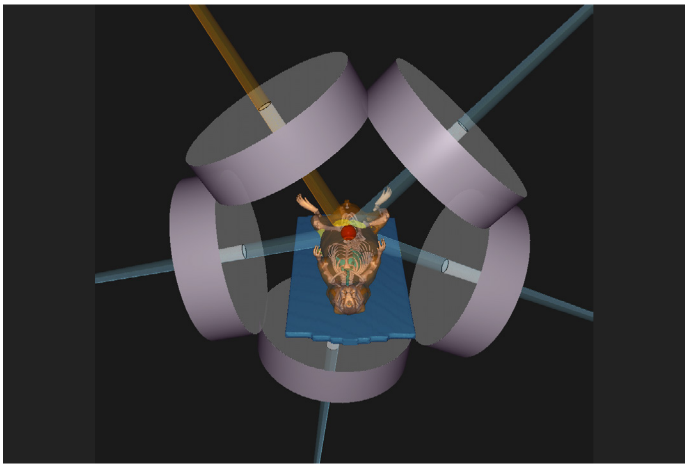

Figure 6. *3D visualization of a plan consisting of five beams.*

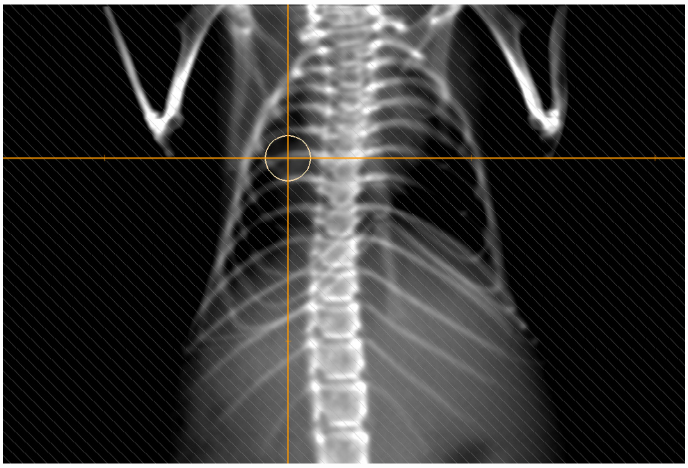

Figure 7. *Beams eye-view, including digitally reconstructed radiograph, of one of the beams from Figure 6.*

REFERENCES

[1] RayStation 9B Reference Manual; 2019
[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] S Chiavassa, R Nilsson, K Clément-Colmou, V Potiron, G Delpon and E Traneus. Validation of the analytical irradiator model and Monte Carlo dose engine in the small animal irradiation treatment planning system µ-RayStation 8B. Phys. Med. Biol. 65 (2020) 035006
[4] R Nilsson and S Chiavassa. Appendix: Results GPU MC. 2020. An appendix to [3]

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