Validation of a commercial Monte Carlo dose calculation algorithm for treatment plan verification

Claudia Gösenbauer[a], Wolfgang Lechner[b], Dietmar Georg[b], Petra Trnková[b]

[a]Universitätsklinik für Radioonkologie, Allgemeines Krankenhaus Wien, Währinger Gürtel 18-20, 1090 Wien
[b]Universitätsklinik für Radioonkologie, Medizinische Universität Wien, Währinger Gürtel 18-20, 1090 Wien

Inroduction

In current clinical practice, every radiotherapy treatment plan calculated with the treatment planning system (TPS) is verified prior to treatment to ensure accuracy of the dose calculation. Such a patient specific QA procedure is mostly performed through multidimensional dosimetric measurements, which are time consuming and machine time intensive, or using independent dose calculation software for calculation based verification procedures. The aim of this work was the clinical validation and implementation of the commercial Monte Carlo (MC) algorithm based software SciMoCa (v1.5.2.3331 IBA, Belgium) for plan verification.

Materials und Methods

A beam model in SciMoCa was created for all available photon beam qualities with (WFF) and without flattening filter (FFF), i.e. energies 6 MV WFF, 10 MV WFF, 6 MV FFF, and 10 MV FFF of a Versa HD linac (Elekta, Sweden), based on basic beam data measurements. For validation of the software, several sets of simple treatment plans calculated on a digital CT water phantom were created in the TPS RayStation (v11A, RaySearch Laboratories, Sweden) for each energy: homogeneous square fields of sizes 2 x 2 cm2, 5 x 5 cm2, 10 x 10 cm2, and 20 x 20 cm2; a circular field with a 10-cm-diameter; a centred “striped field” with 3 stripes of 15 x 5 cm2; an off-axis “striped field” with 4 off-axis stripes of 15 x 3 cm2; two rectangular fields 5 x 30 cm2 and 30 x 5 cm2; and two field-in-field plans using quadratic and rectangular fields. Each field was created with 100 MU at a source surface distance (SSD) of 90 cm. Additionally, the 10 x 10 cm2 field was calculated with SSDs of 80 cm and 100 cm. All rectangular fields were also

calculated with 60° wedges for the WFF energies. Moreover, 134 patient plans (52 3D-CRT, 82 VMAT) were evaluated.

The evaluation of simple treatment plans in SciMoCa was performed with a voxel size of 2 x 2 x 2 mm3, external density threshold switched off, fine minimum uncertainty, dose-to-water calibration and without removing of the couch. The local gamma passing rate (GPR) using a 2% dose difference and 2 mm distance to agreement at a dose cut-off threshold of 10% was analysed. For the evaluation of patient plans, the voxel size was increased to 3 x 3 x 3 mm3. The global GPR was evaluated within the 50 % dose region using 3% dose difference and 3 mm distance to agreement. The results of the SciMoCa dose calculation for 6 patients were compared to measurements performed with the Delta4 phantom (Scandidos, Sweden) using the local GPR at 2% dose difference, 2mm distance to agreement and a dose cut-off threshold of 10%.

Results

The analysis of the simple fields yielded an average GPR of 88% ± 13% (38% to 100%). Considering only square field shapes, the average GPR was 94% ± 7% (71% to 100%). For patient plans the GPR was 97% ± 5% (78% to 100%) for 3D-CRT treatment plans and 99% ± 1% (96% to 100%) for VMAT plans. Comparing the dose calculated by SciMoCa with measurements the GPR was 86% ± 8% (71% to 98%).

Discussion

The lowest GPRs for the simple plans were obtained for either striped fields or wedged beams. Since the Collapsed Cone algorithm used in the TPS is known to be less accurate for low dose regions, a lower GPR was expected for striped fields featuring a large low dose region. As a result, we evaluated the 50% dose region for patient plans further on.

For simple square fields, the 10MV beam with wedge had the lowest GPR, as shown in figure 1. This was due to inaccurate wedge modelling implemented in the TPS. Therefore, the slightly lower GPR of 3D-CRT plans compared to VMAT plans can be explained by the fact that many 3D-CRT plans used 10MV wedged beams. It is expected that the wedge modelling will improve with the implementation of a MC based dose calculation in the TPS.

In conclusion, the dose calculations performed by SciMoCa for clinical treatment plans had excellent agreement with the dose calculations performed by the TPS. The consistency was also confirmed by the comparison with measured dose

distributions. The SciMoCa System was successfully commissioned and benchmarked for clinical use.

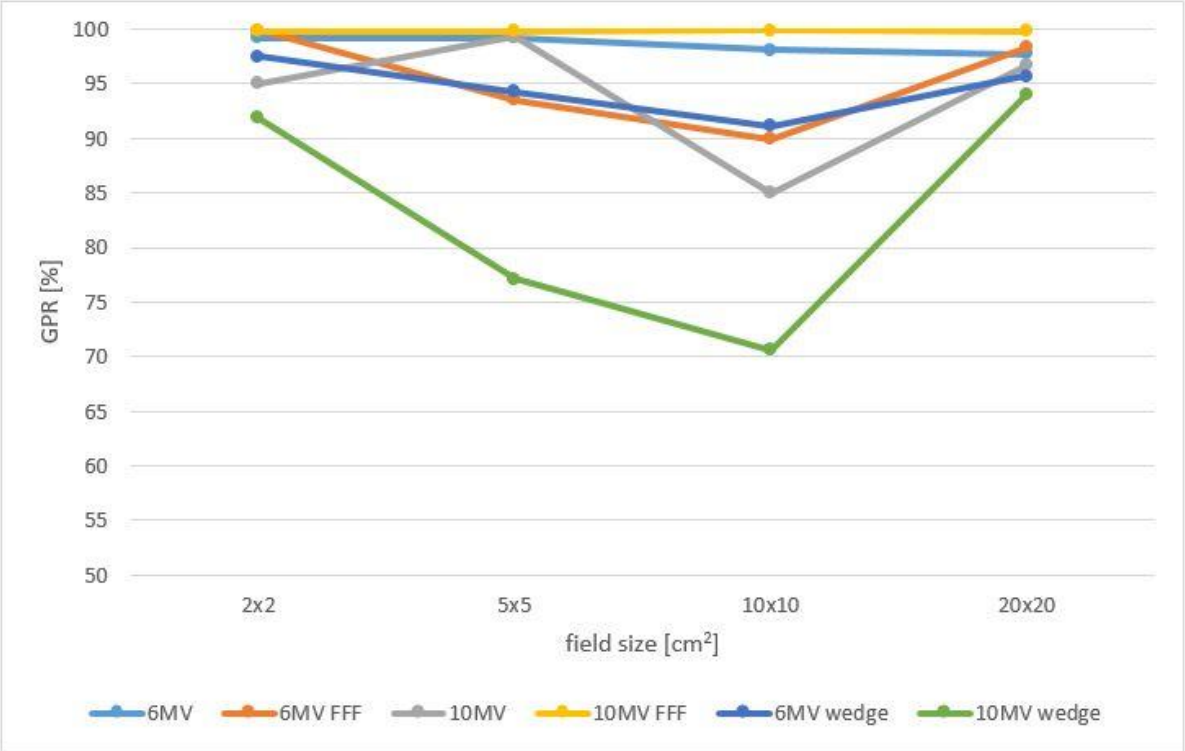

Figure 1: GPR using 2 % dose difference and 2 mm distance to agreement of square fields dependent on energy.