Monte Carlo secondary plan check: validation and definition of the action limits for patient QA

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Purpose

The purposes of this study were 1) to assess the accuracy of 3D dose calculation with Monte Carlo (MC) algorithm of the automated treatment plan verification software SciMoCa v1.4.2 (IBA Dosimetry, Germany/Radialogica, USA) and 2) to establish action limits for plan QA based on the gamma criteria taking into account the sensitivity of SciMoCa to specific plan errors.

Materials & Methods

- The Monte Carlo beam model for 6MV VersaHD linac was commissioned by comparisons between measured data and calculations done with SciMoCa and a MC-based treatment planning system (TPS Monaco 5.11, Elekta). In case of square fields the verification with water phantom measurements was performed, whereas for complex fields and 20 IMRT/VMAT (head, lung, breast) cases SciMoCa was compared to TPS and measurements with 2D-array.
- The same plans were used to determine the sensitivity of the γ-analysis in SciMoCa to treatment plan errors, such as incorrect HU-ED curve selection, structure density override errors or a wrong MLC offset in TPS model.
- Results were correlated with plan complexity indices and used to derive action limits in statistical process control charts for independent calculation-based plan QA with SciMoCa.

Results

- The study shows good agreement between SciMoCa, TPS and measurements for PDDs, profiles and point doses. A maximum difference of 0.4% and 1.5% in output factors was found for $2x2cm^2$ field for SciMoCa vs. measurement and TPS, respectively. For clinical cases 3D γ-analysis (global, 2% dose difference -1mm DTA) vs TPS showed mean values of 99,2% in phantom and 97,5% in patient geometry. Analysis of measured 2D doses with 3%-3mm criteria for all cases showed mean global γ-values of 97.2% and 97.3% and local γ of 94.2% and 94.7% for TPS and SciMoCa doses, respectively.
- The γ-analysis for SciMoCa vs. TPS with 2%-2mm and 2%-1mm criteria showed moderate correlation with gamma pass rates of the TPS calculation vs. measurement QA (r=0.54, p<0.05). Moderate correlation was present between SciMoCa γ-pass rates (2%-2mm and 2%-1mm) and few plan complexity indices: Field Irregularity (FI) (r= -0.66, p<0.05) and product of the FI and Small Segment Contribution index (r=-0.48, p<0.05).

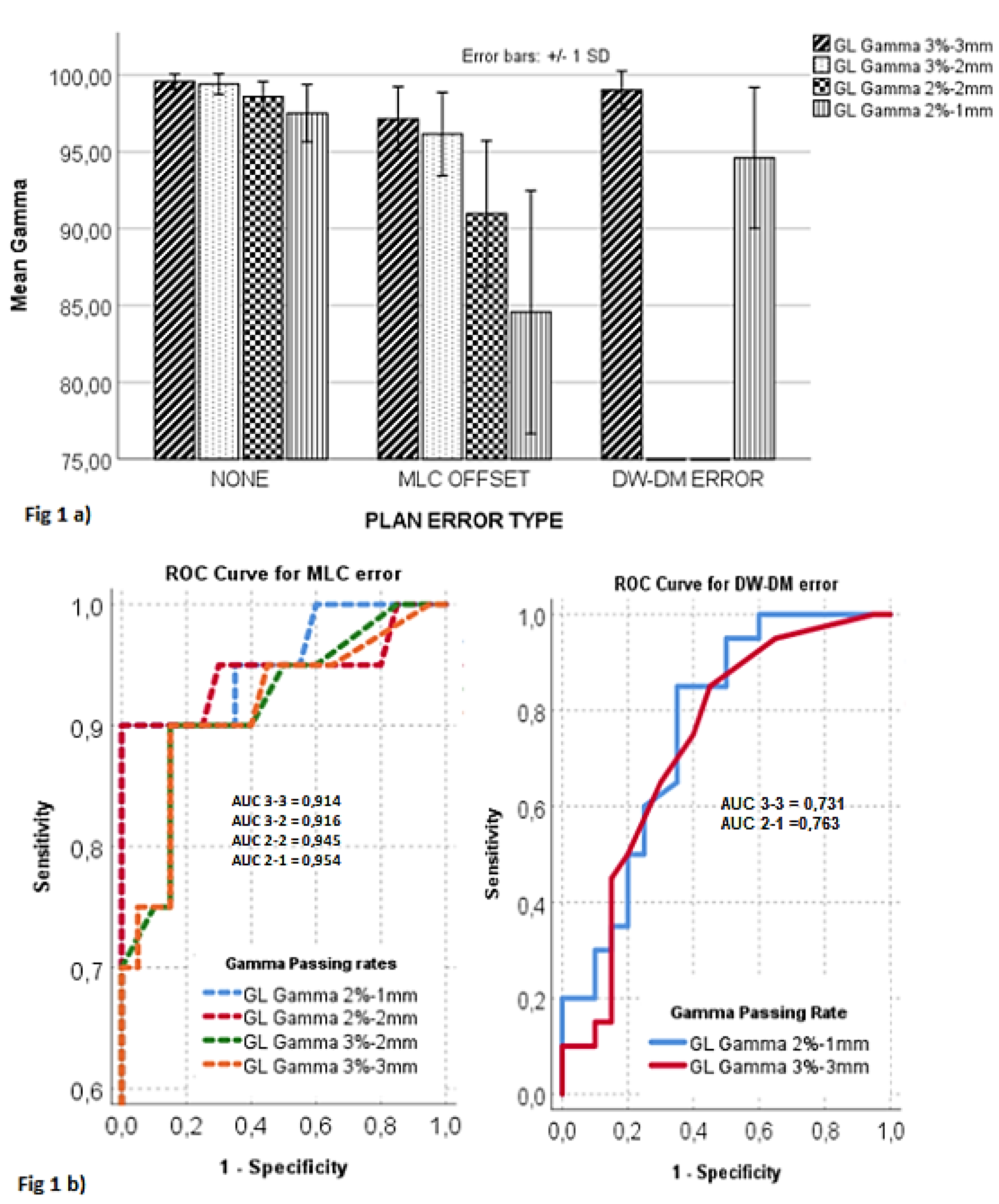

Fig.1 a) Mean gamma passing rates for original plans and with representative induced errors: MLC offset and calculation of dose to water vs. dose to medium. b) ROC curves for different gamma pass rate cut-off values for same induced errors

- SciMoCa plan QA results applying different γ-criteria for all plans with two exemplary induced errors are shown in the Fig 1. For 2%-1 mm γ-criteria sensitivity for MLC offset error detection was above 80% and 90% if the plan is considered passing with γ>90% and >95%, respectively. Errors in density overrides or HU-ED conversion were detected with γ-criteria of 2%-1mm.
- Control charts (QACC) were created for the QA with SciMoCa to be used together with measurement QACC (Fig. 2) and γ-values of 94.5% and 92% were derived as new *warning* and *failed* plan criteria for global gamma analysis at 2%-1mm dose difference and DTA.

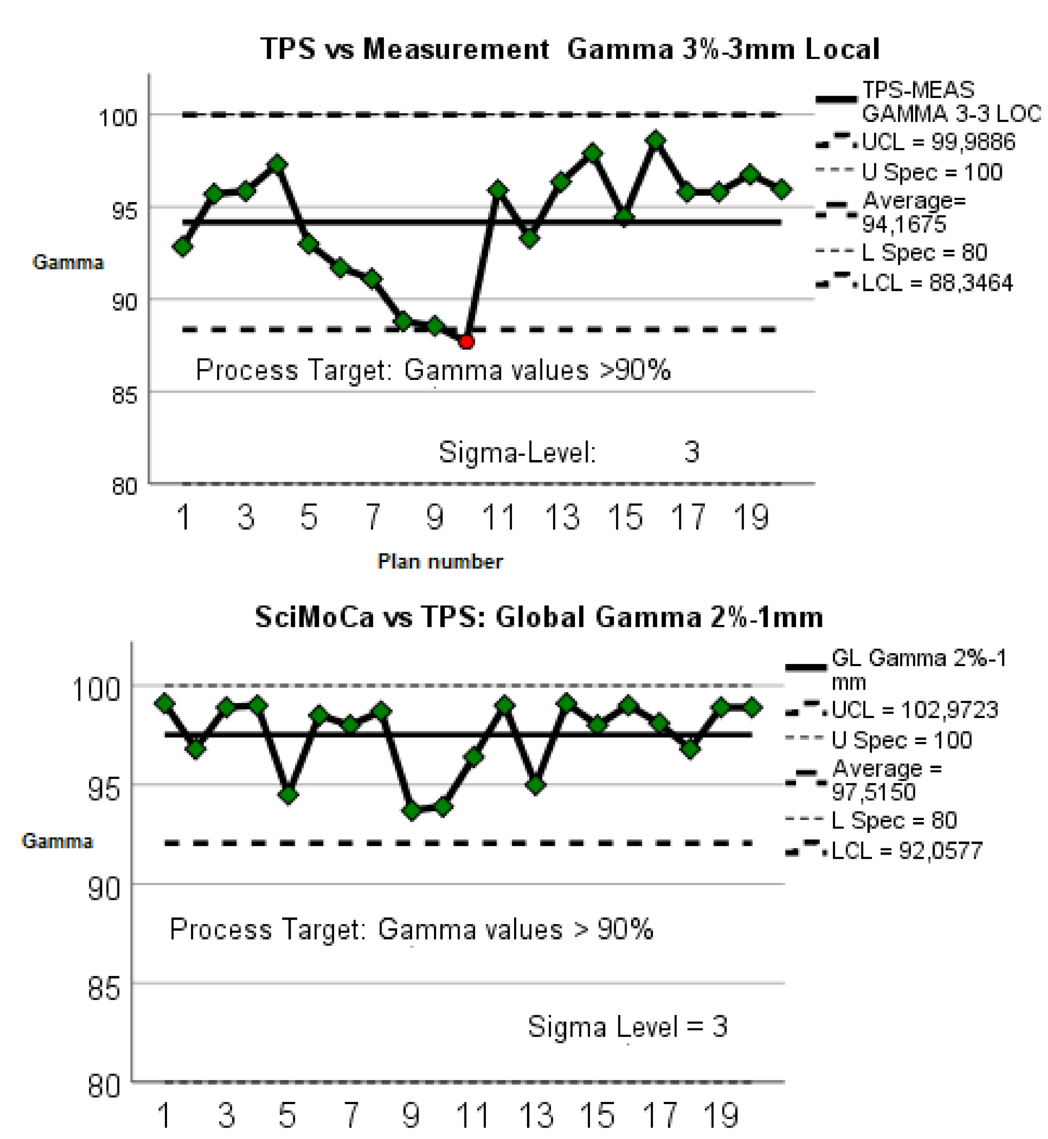

Fig. 2 QA Control Charts for selected gamma analysis criteria in measurement-based QA (above) and MC SciMoCa plan check (below).

Conclusion

The study shows that 3D MC plan verification with tight gamma criteria (2%-2mm and below) provides reliable method to discover clinically relevant errors in beam model and plan parameters, besides rigorous second check of the TPS algorithm. Institution-specific control charts are useful tool to define action limits for calculation-based QA and enhance safety in clinical process.

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