Dosimetric verification and clinical evaluation of PRIMO as an independent Monte-Carlo-based dose verification tool

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Purpose
For highly conformal dose delivery techniques like VMAT there is a need of an independent dose verification procedure. The purpose of this study is to test the Monte-Carlo dose calculation program PRIMO [1] to verify the dose distributions of 6-MV-FF VMAT plans and compare the results with ionization chamber array measurements (IC array) and portal dosimetry measurements (PDM).

Materials and Methods
A clinical accelerator1 in 6-MV-FF mode was commissioned in PRIMO (V.0.3.1.1626) using phase space files [2], distributed by the vendor, for the upper linac head simulation. Field sizes from 3 x 3 cm² up to 40 x 40 cm² were simulated in PRIMO and compared to measured data. Furthermore six VMAT plans (one glioblastoma, two prostate and three head-neck plans) were calculated with the Acuros-XB algorithm8 (dose to medium) and verified in three independent ways:

Options: TPS, IC array II, PRIMO, PDM

Results
For the percent depth dose curves (PDD) and cross profiles (CP) of the different field sizes pass rates greater than 99 % were achieved using a gamma criterion of 2 % and 2 mm. See Fig.1 as an example.

Fig.1: PDD and CP of a 10 x 10 cm² field. The red lines show the measured data, the blue lines the result of the Monte-Carlo simulation with PRIMO. The light blue lines give the differences of both curves.

Comparing the average pass rates of the three different dose verification methods for distinct gamma criteria in Tab.1, there is a very good agreement between the PRIMO and Acuros-XB simulations as well as between the Acuros-XB and PDIP simulations and their corresponding measurement method.

<table>
<thead>
<tr>
<th></th>
<th>Acuros-XB vs. IC array</th>
<th>Acuros-XB vs. PRIMO</th>
<th>PDIP vs. PDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \gamma_{3,3mm} )</td>
<td>(98.1 ± 0.6)</td>
<td>(99.9 ± 0.1)</td>
<td>(99.0 ± 1.5)</td>
</tr>
<tr>
<td>( \gamma_{2,2mm} )</td>
<td>(89.9 ± 2.2)</td>
<td>(98.3 ± 1.9)</td>
<td>(96.4 ± 2.8)</td>
</tr>
<tr>
<td>( \gamma_{1,1mm} )</td>
<td>(53.7 ± 4.9)</td>
<td>(92.5 ± 7.0)</td>
<td>(67.3 ± 10.0)</td>
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</tbody>
</table>

Tab.1: Average accordance between Acuros-XB and PRIMO simulations, Acuros-XB simulations and IC array measurements and PDIP simulations and PDM.

Fig.2 gives an example of a head-neck boost dose distribution simulated in PRIMO and the result of the gamma evaluation \( \gamma_{1,1mm} \) comparing the Acuros-XB and PRIMO simulation. The red areas of the gamma distribution are areas that were the PRIMO dose distribution fails the gamma criterion related to the Acuros-XB simulation and the blue areas are area where the PRIMO dose distribution fulfills \( \gamma_{1,1mm} \). The two algorithms disagree especially in regions of high gradients.

Fig.2: Dose distribution of a head-neck boost plan simulated in PRIMO and the corresponding gamma evaluation \( \gamma_{1,1mm} \) between the PRIMO and Acuros-XB calculation.

Conclusion
PRIMO is a Monte-Carlo-based dose simulation program which gives the possibility of independent dose verification of highly conformal and complex treatment plans. In future cumbersome measurements could be replaced by simulations. Further investigations on the sensitivity of PRIMO for MLC misalignment and dose errors have to be done.

Literature