Benchmarking a flexible Monte Carlo tool based on the DPM code for use in evaluating IMRT treatment planning systems

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Introduction
Measurement-based comparisons have traditionally provided an acceptable assurance in determining an institution’s performance in terms of correct dose delivery. However, there has been growing concern that today’s escalating dose prescriptions, delivered with increased conformity and steep gradients, have pushed the limits of measurement uncertainty. Clinical trial working groups have discussed ways to implement a common tool that can be used to audit all treatment planning system (TPS) dose calculations for quality assurance purposes. One way to address the difficult dosimetry issues is through the use of a trusted independent dose calculation. Monte Carlo dose calculations have been perceived as a complementary method to both measurement and analytical based numerical calculations. Specifically, a new tool comprised of a unique source model and the Dose Planning Method (DPM) code adapted for this purpose is evaluated through verification and benchmark testing that includes: line energy spectra, percent depth dose, profiles, a 3D conformal lung plan with the MLC’s fully retracted, and an IMRT lung plan.

Key Points
• The source model, described by the product of Fatigue and Fermi functions, simulated the energy spectrum from 9 different lines. These spectra were compared to those produced using the BEAM code.
• Verification/benchmark tests for a Varian 6MV photon beam using ion-chamber, thermoluminescent detectors (TLDs), and radiochromic film included:
  • Percent depth dose, profiles, and output factors
  • 3-D and IMRT lung plans using the Radiological Physics Center (RPC) thoracic phantom
• Future tests will include: Elekta and Siemens linacs

Benchmark: Energy spectrum
Figure 1 shows the versatility of the source model to agree well with the BEAM code when comparing the energy spectra from 9 different lines.

Verification: Varian 6MV, Beam data
Figures 2 and 3 show PDD and dose profiles, respectively, of the DPM calculated and measured dose values for a 6MV photon beam, using a 10x10 cm² field-size, in a water phantom at 100 cm SSD. Figure 4 compares the calculated and measured output factors at various field sizes. In general, good agreement exists in all basic commissioning beam data. Development of the horn-effect continues in an effort to better match the measured output factors (normalized at the 10 cm x 10 cm results).

Table 1. 3-D conformal plan point dose comparisons of calculation (DPM and TPS) to TLD measurements.

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Tumor</th>
<th>Heart</th>
<th>Cord</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPM</td>
<td>0.998</td>
<td>1.736</td>
<td>0.993</td>
</tr>
<tr>
<td>Pinnacle</td>
<td>1.008</td>
<td>0.774</td>
<td>1.083</td>
</tr>
</tbody>
</table>

Table 2. IMRT plan point dose comparisons of calculation (DPM and TPS) to TLD measurements.

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Tumor</th>
<th>Heart</th>
<th>Cord</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPM</td>
<td>1.018</td>
<td>1.075</td>
<td>0.993</td>
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<tr>
<td>Pinnacle</td>
<td>1.019</td>
<td>1.053</td>
<td>0.983</td>
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</table>

Conclusions
The Fatigue-Fermi function for the source model fits the photon spectra from various linear accelerator manufacturers making it flexible for use within a generic calculation tool. While more development of the source model is necessary, verification testing of the basic beam data and initial benchmark testing of the 3D and IMRT lung plans demonstrate the viability of this source model approach with the DPM Monte Carlo code in order to make dose calculations for use in quality assurance audit checks.

References