Feasibility of Using the “Irregular Surface Compensator” Planning Tool of the Eclipse Treatment Planning System for Total Body Irradiation Treatment Planning
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Purpose
To investigate the feasibility of using the Irregular Surface Compensator (ISC) planning tool of the Eclipse treatment planning system (TPS) for Total Body Irradiation (TBI) treatment.

Introduction
TBI treatments require that the whole body receives within ±10% of the prescribed dose. Different body parts with different thicknesses compared to the umbilicus separation may receive higher or lower doses compared to the prescribed dose. Another challenge is to keep the lung dose below 10Gy to avoid complications. In order to address this problem, physical compensators [1] and blocks are used during the treatment for different parts of the body and the lungs (Figure 1).

The compensation and the blocking present a challenge during the delivery of the treatment in that they prolong the treatment time due to the patient setup, in-vivo dosimetry measurements and the frequent adjustments of the compensators to conform the dose to prescription during the treatment.

Different groups investigated techniques to plan and deliver the treatments to achieve uniform dose distributions for TBI [2-6]. Linac based IMRT techniques usually involve multi iso-center plans which may present challenges in terms of patient positioning and setup. Although Tomotherapy based TBI treatment techniques may address some of the challenges of the linac-based such as the multi-iso-center plans, Linacs are more widely available.

In this study, we investigated the feasibility of using the “Irregular Surface Compensator” (ISC) planning tool of the Eclipse TPS for TBI treatment planning at an extended SSD.

The accuracy of Eclipse AAA dose calculation algorithm at extended SSDs was investigated by Hussain et al [6] and they concluded that “AAA predicts the dose for 6MV at extended SSDs accurately in an homogeneous medium”. In our study we also verified Eclipse AAA’s dose calculation at the extended SSD.

Eclipse Irregular Surface Compensator Algorithm
Irregular surface compensator algorithm creates a compensation surface based on the surface shape as determined by the body contour [7]. The algorithm takes into account the effects of the beam divergence and the heterogeneities during the generation of compensation surface (Figure 2 left) and the corresponding fluence map generation respectively.

Figure 2: The compensation surface is defined by specifying the desired penetration depth (left). Two opposite ISC fields calculated on a triangular shaped phantom with air showing the dose uniformity across the phantom in three projections (right).

Verification of TPS calculation algorithm with Irregular Surface Compensator at extended SSD
A phantom made up of solid water and styrofoam was constructed (Figure 3). Two 8x8 cm² opposed 6MV fields were placed and calculated with the ISC algorithm to deliver 100Gy at the center of the phantom corresponding to 50% penetration depth.

Optically Stimulated Luminescence Detectors (OSLD) were placed in four locations: three in the air (styrofoam), and one in the solid water. Three of the OSLDs (1 in solid water and 2 in air) were placed off-axis.

Total Body Irradiation Treatment Planning with Irregular Surface Compensator
A Rando phantom (The Phantom Laboratory, Salem, NY) was used for treatment planning. The phantom was scanned in supine position with 0.5cm slice thickness. Prior to the CT scan, OSLDs were placed in three locations in the phantom. The treatment plan was made with 6MV opposed lateral fields to deliver 12Gy in 6 fractions at SSD=220cm. The fluence maps calculated by the ISC algorithm were further modified using Eclipse fluence editor so that the lungs would receive only 10Gy (Figure 4 left). The dynamic MLCs delivered the final fluence by a Varian TrueBeam linac. The plan with lateral fields was delivered on the Rando phantom at 220 cm SSD. The OSLDs were read and compared with the Eclipse TPS calculations.

Figure 4: The fluence map was modified to reduce the dose to lungs to 10Gy (left). The plan with opposed lateral fields was delivered at SSD=220cm (right).

OSLD measurements from the solid water/styrofoam heterogeneous phantom are shown in Table 1. OSLDs #2, 3, and 4 were located inside the styrofoam. OSLDs #3 and 4 were located in field off-axis while #2 is located out-of-field and off-axis. For the in-field OSLDs, the agreement between the OSLD readings and the Eclipse calculated doses are in agreement within 5%. The out-of-field OSLD reading was measured as 35Gy while the calculated dose was 93Gy.

The heterogeneous phantom in-field OSLD reading are in good agreement with Eclipse AAA calculations validating the accuracy of the AAA dose calculations which may be attributed to the known over-response of OSLDs in out-of-field irradiation conditions [8].

The agreement between the ISC generated TBI treatment plan calculated using Eclipse AAA algorithm and OSLD measurements using the Rando phantom also showed good agreement (<5.1%). These two results show that the AAA dose calculations at extended SSD were reliable. ISC generated TBI treatment plan was within 2% of prescription dose as measured with OSLDs at different parts of the phantom. The dose to lungs were at 81% of the prescription dose reducing the lung dose to ~10Gy. ISC generated TBI plan at extended SSD could be a promising alternative to standard TBI treatment planning and delivery techniques. ISC simplifies the compensation and blocking and achieves a uniform dose distribution; hence potentially reduces the treatment time.

Discussion and Conclusion
The heterogeneous phantom in-field OSLD reading are in good agreement with Eclipse AAA calculations validating the accuracy of the AAA at extended SSD. The out-of-field OSLD measurement was 39% higher than the Eclipse AAA prediction which may be attributed to the known over-response of OSLDs in out-of-field irradiation conditions [8].

The agreement between the ISC generated TBI treatment plan calculated using Eclipse AAA algorithm and OSLD measurements using the Rando phantom also showed good agreement (<5.1%). These two results show that the AAA dose calculations at extended SSD were reliable. ISC generated TBI treatment plan was within 2% of prescription dose as measured with OSLDs at different parts of the phantom. The dose to lungs were at 81% of the prescription dose reducing the lung dose to ~10Gy. ISC generated TBI plan at extended SSD could be a promising alternative to standard TBI treatment planning and delivery techniques. ISC simplifies the compensation and blocking and achieves a uniform dose distribution; hence potentially reduces the treatment time.

References

Table 1: The solid water phantom measurements and Eclipse calculated doses are shown.

<table>
<thead>
<tr>
<th>OSLD #</th>
<th>Location</th>
<th>Measured Dose (cGy)</th>
<th>Eclipse Dose (cGy)</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Solid water</td>
<td>109.2</td>
<td>113.0</td>
<td>-3.4</td>
</tr>
<tr>
<td>2</td>
<td>Styrofoam</td>
<td>35.1</td>
<td>9.0</td>
<td>-75.7</td>
</tr>
<tr>
<td>3</td>
<td>Solid water</td>
<td>108.2</td>
<td>100.0</td>
<td>-8.0</td>
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<tr>
<td>4</td>
<td>Styrofoam</td>
<td>95.1</td>
<td>100.0</td>
<td>-4.9</td>
</tr>
</tbody>
</table>

Table 2: The solid water phantom measurements and Eclipse calculated doses are shown.

<table>
<thead>
<tr>
<th>OSLD location</th>
<th>Eclipse measured dose [cGy]</th>
<th>Calculated dose [cGy]</th>
<th>5% difference</th>
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<tbody>
<tr>
<td>neck</td>
<td>208.4</td>
<td>100.2</td>
<td>105</td>
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<tr>
<td>lung</td>
<td>162.2</td>
<td>81.1</td>
<td>81.9</td>
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<tr>
<td>umbilicus</td>
<td>196.1</td>
<td>98.0</td>
<td>208.9</td>
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