MULTIPLE METASTASIS INSERT FOR THE LUCY 3D QA PHANTOM

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INTRODUCTION

An investigation of the multiple metastasis (MM) insert for the Lucy 3D QA phantom from Standard Imaging was performed at the McLeod Health Center in the spring of 2017. The goal of this investigation was to test the MM insert in a clinical environment. The main task was to assess the utility of the MM insert as a potential tool for commissioning treatment planning systems that include a single isocenter technique for treating multiple targets simultaneously. A review of the steps taken in this study and general comments and suggestions with respect on user friendliness are included in this report.

MATERIALS

BrainLab thermoplastic mask system

Lucy 3D QA Phantom with the following inserts:

- MM insert (Figure 1)
- Stacked film insert
- Ion chamber insert (mid-chamber, A16)
- CT marker cylinder inserts (x4)
- Exradin A16 microchamber
- Standard Imaging SuperMAX electrometer
- Gafchromic EBT3 film

Figure 1: Render of the MM insert
METHODS

The Lucy 3D QA Phantom was assembled with the mid-chamber ion chamber insert (Exradin A16 microchamber) and the MM insert. The phantom was then used as the patient surrogate to create a mask for use in properly positioning the phantom from CT imaging to treatment. To accomplish this, natural recesses in the Lucy phantom (generally filled by nylon screws or plugs) were used to create “registration points” in the thermoplastic mold. In this way, the phantom could only be aligned in a particular orientation, thereby creating a “reproducible” setup on the treatment unit at time of testing. Additional care was taken to ensure that the Lucy phantom was level during mask construction to facilitate the proper measurement of the coronal dose plane (this was verified by assessing the “levelness” of the phantom using the observed film planes on the acquired CT).

Following the construction of the mask, the Lucy phantom was scanned on a Radiation Oncology dedicated CT scanner. This scan was transferred to BrainLab Elements – Automatic Brain Metastases Planning (ABMP) for treatment planning.

An additional scan was acquired after the replacement of the MM insert with the stacked film (SF) insert, again taking care to orient the phantom accordingly using the previously constructed mask to provide for the registration. This scan was transferred to ABMP for use in the Phantom Definition module. This phantom configuration (ion chamber insert, stacked film insert, and CT marker cylinder set) was also used for treatment delivery.

A treatment plan was developed using the four 4 mm Tungsten inserts of the MM insert and the tip of the A16 chamber volume as the potential “targets” for the planning system. Variable margins from 1-6 mm were added to each “target”. In addition, variable dose prescriptions were used for each target. See Table 1 below for details of the target structures and dose prescriptions. The planning system determined an optimal plan consisting of 6 dynamic conformal arcs to deliver the prescribed doses indicated below to 99.5% of the contoured target volume (plus the indicated margin).

<table>
<thead>
<tr>
<th>TARGET DESIGNATION</th>
<th>MARGIN (MM)</th>
<th>DOSE PRESCRIBED (Gy)</th>
<th>VOLUME (cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A16</td>
<td>6</td>
<td>8</td>
<td>2.215</td>
</tr>
<tr>
<td>MET 01</td>
<td>2</td>
<td>12</td>
<td>0.823</td>
</tr>
<tr>
<td>MET 02</td>
<td>3</td>
<td>10</td>
<td>1.054</td>
</tr>
<tr>
<td>MET 03</td>
<td>2</td>
<td>12</td>
<td>0.654</td>
</tr>
<tr>
<td>MET 04</td>
<td>1</td>
<td>10</td>
<td>0.343</td>
</tr>
</tbody>
</table>
The resulting treatment plan was then delivered to the Lucy phantom, with the stacked film insert taking the place of the multiple metastases insert. CBCT and ExacTrac imaging were performed prior to treatment to ensure proper positioning and orientation. Gafchromic EBT3 film was cut precisely to fit within the stacked film insert at locations corresponding to the center of each of the 4 target volumes (Tungsten spheres, 4 mm diameter). These locations correspond to planes 2, 6, 8, and 12 according to the documentation accompanying the insert (Figure 2).

![Figure 2: Render of film and target locations](image)

Additionally, an Exradin A16 microchamber was inserted for measurement of the dose at the target location designated "A16". A dose calibration factor based on the nominal linear accelerator output was determined prior to irradiation to calculate the dose to the A16 chamber.

Films were allowed to sit in a dark, humidity-controlled location for 48 hours prior to scanning and processing.
Results

Results of the ion chamber measurement are seen in Table 2:

<table>
<thead>
<tr>
<th>DOSE CONVERSION FACTOR</th>
<th>TOTAL CHARGE MEASURED BY A16 (nC)</th>
<th>CALCULATED DOSE TO A16</th>
<th>REPORTED DOSE FROM PLANNING SYSTEM (MEAN)</th>
<th>% ERROR FROM REPORTED DOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>409.4</td>
<td>2.157</td>
<td>8.83</td>
<td>8.97</td>
<td>-1.56%</td>
</tr>
</tbody>
</table>

Table 2: Ion chamber measurement results

Evaluation of the relative dose distribution was performed using film dosimetry and Dose Lab Pro from Mobius Medical Systems. Gamma analysis (3%/2 mm, and 5%/1 mm, 10% threshold) was performed on each of the planar films, as well as dose distribution comparison. The results for each film plane are seen in Table 3:

<table>
<thead>
<tr>
<th>FILM PLANE</th>
<th>GAMMA PASS RATE (3%/2 MM)</th>
<th>GAMMA PASS RATE (5%/1 MM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>96.2%</td>
<td>97.2%</td>
</tr>
<tr>
<td>6</td>
<td>96.0%</td>
<td>94.0%</td>
</tr>
<tr>
<td>8</td>
<td>94.6%</td>
<td>93.9%</td>
</tr>
<tr>
<td>12</td>
<td>98.4%</td>
<td>95.1%</td>
</tr>
</tbody>
</table>

Table 3: Gamma pass rates for the film slices analyzed.

The figures below show a snapshot of the gamma evaluations performed for each film slice (Figures 3-5):

Figure 3: Calculated and measured dose heat maps for film plane 2 of the insert (left). Gamma passing rate (right).
Figure 4: Calculated and measured dose heat maps for film plane 6 of the insert (left). Gamma passing rate (right).

Figure 5: Calculated and measured dose heat maps for film plane 8 of the insert (left). Gamma passing rate (right).

Figure 6: Calculated and measured dose heat maps for film plane 12 of the insert (left). Gamma passing rate (right).
The Lucy 3D QA Phantom is a well-established phantom for use in commissioning and end-to-end testing of treatment planning systems, including radiosurgery applications. The multiple metastases (MM) insert and available stacked film insert offer a unique opportunity to validate single isocenter, multiple target (SIMT) treatment delivery techniques, which are highly advantageous in the clinical environment. SIMT offers a significant time savings in both treatment planning and delivery, as well as being advantageous for the patients that we treat.

The MM insert proved to be relatively easy to use. Great care should be taken in initially setting up the phantom with the insert for CT and planning, as any error in the setup of the “plane of choice” (coronal, sagittal, or axial) will impact the accuracy of the dose plane exported from the planning system. However, with proper care and precautions, the Lucy phantom and insert can provide a solid foundation for the performance of commissioning and ongoing (annual) quality assurance of treatment planning systems.

The results indicated above are offered as an initial evaluation of the MM insert for Lucy. User technique and geographic markings on the films or inserts could be used to improve the listed results.