INVESTIGATION OF A MODIFIED ELECTRONIC PORTAL IMAGING DEVICE FOR IMPROVING DOSIMETRY IN RADIOTHERAPY

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A thesis submitted for the degree of Doctor of Philosophy (Physics) from the Faculty of Science and Information Technology, University of Newcastle

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DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying subject to the provisions of the Copyright Act 1968.

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I hereby certify that the work embodied in this thesis has been done in collaboration with other researchers. I have included as part of the thesis a statement clearly outlining the extent of collaboration, with whom and under what auspices.

Mahsheed Sabet
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ABSTRACT

In modern radiotherapy treatments such as Intensity Modulated Radiation Therapy (IMRT), megavoltage beams are delivered using plans that usually include sharp dose gradients. Therefore, high resolution dosimetry devices which provide accurate two-dimensional data are required to ensure the correct delivery of radiation fields. There has been growing interest on using Electronic portal imaging devices (EPIDs) for dosimetry applications. A major problem associated with amorphous silicon (a-Si) EPIDs for transit dosimetry is the presence of a phosphor layer, which can introduce large deviations from water-equivalent behaviour due to energy-dependent response and visible light scattering.

In the present study, the phosphor scintillator screen and all other layers above it were removed from the structure of a research-dedicated a-Si EPID and were replaced by buildup layers. The modified EPID (to direct detection configuration) was evaluated for dosimetry applications by comparison to ionization chamber in water measurements for 6 and 18 MV treatment beams. The indirect (unmodified) EPID was similarly investigated in transit dosimetry conditions for comparison. The direct EPID with 3 cm solid water buildup showed water-equivalent response in all tested conditions except for very thick phantoms in 6 MV beams which could be easily corrected, while the indirect EPID was sensitive to changes in field size, phantom thickness and off-axis distance. Some of the EPID characteristics which could affect dosimetry measurements (such as dose rate dependence and image lag) were also investigated for both EPID configurations.

The direct EPID was tested for absolute dosimetry measurements with slab and anthropomorphic phantoms in a number of clinical IMRT fields by comparison to a two dimensional array of ionization chambers used as reference and the Gamma evaluation (3%, 3 mm criteria) showed that on average 97.9% of points had a Gamma index less than 1.

Monte Carlo method was used to simulate the head of a linear accelerator for 6 MV beams (using BEAMnrc) and the direct EPID (using DOSXYZnrc). The models were then used to simulate the same transit dosimetry conditions as used for the measurements. The agreement of the relative measured and simulated image profiles on the central axis were within 3% for square fields with slab phantoms in the beam. For a
head and neck phantom in a dynamic IMRT beam, the Gamma evaluation of measured and simulated relative dose images showed 80.3% of points with Gamma index less than 1 (3%, 3 mm criteria).

A simple measurement-based correction model was also developed to correct the EPID images and use them for water-equivalent transit dosimetry without the application of any kernels. The model was tested by comparison of the absolute dose images measured by the EPID and a reference two dimensional array of ionization chambers for clinical IMRT fields in transit conditions, and as a result on average 99.5% of points had a Gamma index less than 1 (3%, 3 mm criteria).

The only drawback of using the EPID in direct configuration is the poor quality of images compared with the indirect EPID. If direct EPIDs are used as two-dimensional dosimeters mounted on linacs, on-board kilovoltage imaging devices could be used as an alternative for the EPID (as imager) to confirm patient positioning.
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AMFPI</td>
<td>Active Matrix Flat Panel Imager</td>
</tr>
<tr>
<td>a-Si</td>
<td>amorphous silicon</td>
</tr>
<tr>
<td>CCD</td>
<td>Charge Coupled Device</td>
</tr>
<tr>
<td>d_{max}</td>
<td>depth of maximum dose</td>
</tr>
<tr>
<td>dEPID</td>
<td>direct Electronic Portal Imaging Device</td>
</tr>
<tr>
<td>DF</td>
<td>Dark Field</td>
</tr>
<tr>
<td>EPI D</td>
<td>Electronic Portal Imaging Device</td>
</tr>
<tr>
<td>FF</td>
<td>Flood Field</td>
</tr>
<tr>
<td>FWHM</td>
<td>Full Width at Half Maximum</td>
</tr>
<tr>
<td>iEPID</td>
<td>indirect Electronic Portal Imaging Device</td>
</tr>
<tr>
<td>Linac</td>
<td>Linear accelerator</td>
</tr>
<tr>
<td>MLC</td>
<td>Multi-Leaf Collimator</td>
</tr>
<tr>
<td>MU</td>
<td>Monitor Unit</td>
</tr>
<tr>
<td>OAR</td>
<td>Off Axis Ratio</td>
</tr>
<tr>
<td>SDD</td>
<td>Source to Detector Distance</td>
</tr>
<tr>
<td>SLIC</td>
<td>Scanning Liquid-Filled Ionization Chamber</td>
</tr>
<tr>
<td>EPI D</td>
<td>EPI D</td>
</tr>
<tr>
<td>TLD</td>
<td>Thermo-Luminescent Dosimeter</td>
</tr>
<tr>
<td>TMR</td>
<td>Tissue Maximum Ratio</td>
</tr>
<tr>
<td>VEPID</td>
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