A novel paediatric bowtie filter for ultra-low dose CBCT guided radiotherapy.

Abigail Bryce-Atkinson¹; Tom Marchant²; Marianne Aznar¹; Gillian Whitfield³,⁴; Marcel van Herk¹

¹Division of Cancer Sciences, School of Medical Science, Faculty of Biology, Medicine and Health, The University of Manchester, Manchester, UK.
²Christie Medical Physics and Engineering, The Christie NHS Foundation Trust, Manchester, UK.
³Manchester Academic Health Science Centre, The Christie NHS Foundation Trust, Manchester, UK.
⁴The Children’s Brain Tumour Research Network, The University of Manchester, Royal Manchester Children’s Hospital, Manchester, UK.

INTRODUCTION
CBCT guided radiotherapy increases accuracy of treatment delivery, however, frequency and use of CBCT for setup varies between centres [1,2]. Imaging dose concerns mean that even the lowest clinically available CBCT dose setting is often considered too high for daily imaging.

This work presents ultra-low dose CBCT through use of a bowtie filter specifically designed for children: reducing exposure and shaped to fit their smaller body sizes.

METHODS
An ATOM 10 year old phantom was scanned using the standard (adult) and paediatric bowtie filter (Fig. 1). Scans simulated as if acquired with the bowtie filter were simulated by addition of noise corresponding to the paediatric filter profile [3].

The simulated phantom scans were validated by comparison to the acquired phantom scans. The simulated method was then applied to 20 paediatric CBCTs.

Image quality and registration accuracy was assessed by 4 experienced radiographers: comparing bony anatomy registration to the full dose scans. Automatic registration followed by manual adjustment was performed.

Dose reduction was calculated through a GATE-based Monte Carlo model of the Elekta XVI system on UF/NCL hybrid computational phantoms of different ages.

Fig. 1: Left: The dimensions of the Elekta F1 adult bowtie filter (black) overlaid with dimensions of the new paediatric bowtie filter (blue) showing the difference in thickness and shape. Right: The manufactured bowtie filter.

RESULTS
The paediatric bowtie filter reached a fivefold reduction in effective dose according to the Monte Carlo dose calculation (Table 1). Bone/soft tissue boundaries remained clear in the simulated scans, despite increased noise (Fig. 2).

All acquired phantom scans and simulated patient scans had registration discrepancies within 1mm or 2 degrees for translation and rotational directions.

Fig. 3 shows the observer variation in translational registration discrepancies, demonstrating no considerable impact on accuracy in comparison to the clinically used scan with the adult filter.

Table 1: Table of effective dose for different ages of UF/NCL phantoms calculated by Monte Carlo modelling. The Paediatric filter resulted in a fivefold dose reduction.

<table>
<thead>
<tr>
<th>Phantom age (years)</th>
<th>Standard filter (mSv)</th>
<th>Paediatric filter (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.22</td>
<td>0.05</td>
</tr>
<tr>
<td>5</td>
<td>0.23</td>
<td>0.05</td>
</tr>
<tr>
<td>10</td>
<td>0.10</td>
<td>0.02</td>
</tr>
</tbody>
</table>

CONCLUSION
A novel bowtie filter optimised for children has been evaluated in 20 paediatric patients.

CBCT scan dose can be reduced fivefold whilst maintaining sufficient registration accuracy for bony anatomy. This could alleviate concerns over late effects due to imaging dose, allowing for daily CBCT set up and thus more accurate treatment for children.

REFERENCES