Use of SPC techniques to generate assessment criteria for transit dosimetry analysis of lung SABR treatments

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Introduction
When introducing a clinical transit dosimetry programme analysis criteria and failure thresholds should be established. Conventional assessment of delivery using quasi-3D phantoms is usually performed using the γ parameter. A common threshold for gamma success is 95% of points with a γ<1 using parameters of 3%/3mm. However any transit dosimetry analysis must allow for clinically insignificant natural variation in the patient setup and the patients contour, effects which do not exist during a phantom measurement.

The aim of this work is to use measured data to establish clinically relevant parameters for the analysis of Lung SABR treatments.

Methods and Materials
At Leeds Cancer Centre lung SABR treatments are planned on Elekta Monaco and delivered using a single arc 6MV FFF VMAT technique on Elekta VersaHD linacs. The patient position is verified using CBCT before every fraction. A portal movie image measured during the treatment delivery is used to reconstruct the delivered dose distribution on the 3D planning CT using the Elekta iViewDose software. The iViewDose software uses the back projection algorithm developed at the NIKI (Mans (2010)). The iViewDose application compares the reconstructed and planned dose distributions and provides analysis points of the delivered dose distribution within the 50% isodose in terms of

• Dose at the Dose Reference Point (DRP). For Lung SABRs the DRP was positioned at the centre of the PTV
• The percentage of points that have a gamma less than one for certain gamma criteria.
• The mean gamma value.
• The gamma value which is exceeded by 1% of the points

During a pilot phase dose reconstructions were analysed using gamma parameters of 3% dose difference and 3 mm distance-to-agreement. Mean values and confidence limits for all of the analysis parameters were calculated using statistical process control methodologies (Pawlack and Gouldstone 2005). The mean and confidence limits were measured from the first twenty fractions to be analysed, ignoring the obvious outliers. The confidence limits were calculated by first calculating the difference between the consecutive results to generate the moving range (MR). The limits are then calculated using the equation.

\[ UCL = \bar{x} + 2.66 \times MR \]
\[ LCL = \bar{x} - 2.66 \times MR \]

Following clinical implementation the reconstructions were analysed against the criteria established in the pilot phase. Where fractions passed all the criteria no further action was taken. Where one or more of the criteria failed the fraction was investigated. The investigations first ascertained whether the analysis was valid, i.e. whether the data was correct and complete. If the analysis was valid the CBCT data from the fraction was interrogated to determine whether there was a contour change or tumour shrinkage. If the patient anatomy was unchanged an independent measurement was undertaken to validate the accuracy of treatment delivery.

Results
32 Fractions were analysed during the pilot phase to determine the mean and upper and lower confidence limits for each of the parameters. Data from fractions that were clearly outside the norm were ignored. Table 1 shows the SPC parameters determined from the pilot data.

84 fractions were analysed in the clinical phase. The results from the all phases for the gamma analysis and point dose analysis are shown in figures 1 and 2. All of the fractions that failed at least one test were investigated. Almost all of the failures were true positives in that a reason could be identified for their failure; tumour motion, contour change, or oedema. Only one patient exhibited a failure which could not be explained due to anatomical changes. This was verified using a Delta4 system and the delivered distribution was found to be in good agreement with the planned distribution.

Conclusion
Transit dosimetry can be an effective tool in determining deviations from intended treatment. Errors identified using transit dosimetry correlated well with anatomical changes identified using CBCT. No errors were identified due to treatment delivery errors.

SPC techniques can be used to develop assessment criteria for transit dosimetry analysis. This should be performed on a site by site basis as different anatomical sites will yield different expected results and confidence levels depending upon the accuracy of the reconstruction and the normal anatomical variability of the site.

Table 1 SPC control variables and iViewDose analysis criteria for Lung SABR treatments.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean/Target</th>
<th>Lower Limit</th>
<th>Upper Limit</th>
<th>Confidence Level</th>
<th>Threshold Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Difference from Mean</td>
<td>6.67</td>
<td>-3.7</td>
<td>5.1</td>
<td>±1%</td>
<td>4%</td>
</tr>
<tr>
<td>Mean and Median % DRP</td>
<td>100</td>
<td>91%</td>
<td>-</td>
<td>±1%</td>
<td>91%</td>
</tr>
<tr>
<td>Mean Gamma of Points (γ&lt;1)</td>
<td>0.42</td>
<td>0.28</td>
<td>0.55</td>
<td>±0.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Upper Limit of Points (γ&lt;1)</td>
<td>1.08</td>
<td>0.72</td>
<td>1.46</td>
<td>±1.5</td>
<td>1.5</td>
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</tbody>
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