Measuring photon beam energy through EPID image analysis of physically wedged fields

S.M. Dawoud1, J. Mason1, I. Bond1, G.C. Ward1, P.A. Rixham1, A. Huckle1, J. Sykes1, S. Weston1
1Leeds Teaching Hospitals NHS Trust, Radiotherapy Physics, Leeds, United Kingdom

Purpose/Objective: To establish a method by which linac photon beam energy can be accurately measured through EPID image analysis with a view to clinical implementation as part of an automated linac QA routine.

Materials and Methods: An Elekta Synergy platform linac was used to produce photon beams of nominal 6MV effective energy. Each beam was configured to give effective energies off-set from the nominal value by altering bending current parameters and dose rates. The effective energies of each beam were established by using a PTW plotting tank to measure PDD profiles in water from which PDD at 10cm (PDD10) was recorded. Subsequently, images of wedged fields (through a physical wedge) were acquired using the EPID panel for each beam. The wedge profile produced in the EPID panel signal is a function of energy due to the energy dependence of the wedge attenuation response and beam hardening effects. A simple metric for characterising this energy-dependent response was found by measuring the ratio of signal from ROIs under the thick and thin portions of the wedge. The ROI ratio was plotted against the measured PDD10 values for each beam in order to establish a calibration curve between the EPID image analysis method and the gold-standard plotting tank method.

Results: Plotting tank PDD curves and EPID images were acquired for beam configurations over three different sessions. The positions and shapes of the ROIs within the EPID image for each exposure are shown below (512 pixels refers to centre of field from image edge). In each case, there was a linear agreement (negative correlation) between the EPID ROI ratios and the measured PDD10 values (results plotted below). The combined results gave good agreement to a linear fit ($R^2 = 0.97$). Uncertainty in the ratio values was found to be dominated by set-up variability; the magnitude of this error was evaluated by repeating the experimental set-up and was found to be a 0.24%. This is comparable to the uncertainty associated the measurement of PDD10 in the water-tank ($\pm 0.30\%$).

Conclusions: A method for measuring photon beam energy using EPID image analysis was established. The new method provides comparable accuracy to the direct measurement of PDD10 in the water-tank, indicating that the measurement technique can provide a reliable metric of energy relative to the gold-standard (i.e. PDD10). Furthermore, this measurement technique does not require additional QA equipment, can be performed in significantly less time and can be integrated into an automatic computer-driven QA process.

EP-1293
To improve image quality of DRR by reducing CT slices increment from raw data reconstruction
C.H. Wu1, K.Y. Hsiao1, Y.F. Chen1
1E-Da Hospital, Department of Radiation Oncology, Kaohsiung City, Taiwan

Purpose/Objective: Image-guidance navigation has become a frequently used technology that provides accurate radiation treatment by using 2D verification with DRR (Digital Reconstruction Radiograph) or 3D registration with planning CT images. The setup uncertainties can be minimized and the dose of normal tissue can be reduced. Hence, the image quality of DRR, especially blurring of bony structures is one of the key factors that define the precision of the treatment. Blurring is mainly caused by interpolating information between image slices and is related with slice thickness and increment. These parameters are usually set to compromise with machine settings, scanning time, patient dose or image noise. The purpose of this study is to reduce blurring of DRR by reducing the CT slices interval from raw data reconstruction.

Materials and Methods: The studied CT images were acquired with Siemens Emotion Duo and analyzed using Matlab 2009a. For phantom study, a 6×5×5 cm³ acrylic phantom was scanned and four image sets (m1, m2, m3, m5) were obtained with four slice thickness settings (1, 2, 3 and 5mm). Except m1, the distance of two adjacent slices is reduced to 1mm increment by insert CT images reconstructed from raw data to produce other three images sets (m2_c, m3_c, m5_c). Then DRR was reconstructed by linear interpretation and the 2-axis profiles are analyzed by area under curve (AUC) and penumbra (10% to 90% of mean maximum value). Under IRB’s permission, the C3 to C5 spine of one head and neck patient was scanned with 1mm and 3mm slice thickness. The Coronal images were compared with/without 1mm increment (p1, p3, p3_c).

Results: The AUC and penumbra of phantom study are demonstrated in Table 1. The AUC of m1 profile is the reference to calculate percent AUC error: (AUC-AUCm1)/AUCm1. We found that percent AUC error and penumbra was increased when the slice thickness is increased. This phenomenon can be improved by decreasing the slice distance from insert images with raw data reconstruction. Benefit of the proposed method is also evident in Figure 1 that shows the patient’s DRRs with different slice thickness settings and reconstruction methods. All the images on the left side have been mirrored for easier comparison. Figure 1a: 1mm vs. 3mm slice thickness; b: 1mm vs. 3mm slice thickness increment to 1mm; c: 1mm vs. 3mm slice thickness increment to 1mm. Image from 1mm slice thickness shows the best clarity of detail and the images are fuzzier with increased increment. But in figure 1c, the arrow points out a less ambiguous space between the vertebra bodies using the decreased slice interval reconstruction.

Table 1

<table>
<thead>
<tr>
<th>m1</th>
<th>m2</th>
<th>m3</th>
<th>m5</th>
<th>m2_c</th>
<th>m3_c</th>
<th>m5_c</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUC(%)</td>
<td>0</td>
<td>-0.95</td>
<td>-1.92</td>
<td>-3.97</td>
<td>-0.60</td>
<td>-1.35</td>
</tr>
<tr>
<td>penumbra</td>
<td>2.00</td>
<td>3.12</td>
<td>4.74</td>
<td>7.79</td>
<td>2.62</td>
<td>3.67</td>
</tr>
</tbody>
</table>

Conclusions: According to this study, the quality of DRR can be easily improved by reconstructing more images between original images. No compromise with scanning time, patient dose or image noise and beneficial for image-guided radiation therapy.

EP-1294
A new technique for quick assessment of mechanical isocenter
J. Heikkilä1, T. Lahtinen1, J. Nustinen1, A. Vanne1
1Kuopio University Hospital, Cancer Center, Kuopio, Finland
2Delfin Technologies Ltd, Kuopio, Finland
3Kuva Ltd, Kuopio, Finland

Purpose/Objective: The measurement of a mechanical isocenter is a basic measurement of the linear accelerator QA tests. The isocenter is usually inspected using two mechanical pointers, one fixed and another moving with gantry, collimator or couch. The accuracy of this check is of the order of millimeters than sub-millimeters. Therefore, trends in size and place of the isecenter over time are hard to register. In this study, a photographing and 3D modelling based QA tool for the assessment of the mechanical isocenter was developed. (The developed software includes tools for image preparation, isocenter visualization and trend analysis).

EP-1295
To improve image quality of DRR by reducing CT slices increment from raw data reconstruction
C.H. Wu1, K.Y. Hsiao1, Y.F. Chen1
1E-Da Hospital, Department of Radiation Oncology, Kaohsiung City, Taiwan

Purpose/Objective: Image-guidance navigation has become a frequently used technology that provides accurate radiation treatment by using 2D verification with DRR (Digital Reconstruction Radiograph) or 3D registration with planning CT images. The setup uncertainties can be minimized and the dose of normal tissue can be reduced. Hence, the image quality of DRR, especially blurring of bony structures is one of the key factors that define the precision of the treatment. Blurring is mainly caused by interpolating information between image slices and is related with slice thickness and increment. These parameters are usually set to compromise with
Materials and Methods: The system to check the mechanical isocenter consists of a standard high-resolution photography camera, remote triggering of camera images, flash module, modified front pointer and a 3D software (patent of Delfin Technologies Ltd, Kuopio, Finland). The linac manufacturer delivered frontpointer was modified by adding a sphere with a radius of 10 mm into the tip of the pointer. This sphere was used as an image object. Its center at all gantry, collimator and couch angles was calculated by the developed software. To start the measurement, the isocenter was first pointed by the laser system. Next, the variation of the sphere center at all gantry, collimator and couch locations was calculated. The map of the center points produces a 3D map of the mechanical isocenter. The weighted point of the isocenter map defines the place of the isocenter and the accuracy of the isocenter.

Results: Feasibility tests of the developed system have been performed using Varian 600C and 2100 C/D linear accelerators. The results on the sub-millimeter accuracy with these old linacs indicate that the diameter of the isocenter with our Varian 600C has exceeded the IEC acceptance limit of 2.5 mm for mechanical isocenter.

Conclusions: The new sub-millimeter mechanical isocenter test should be included in the routine tests of the QA procedure. Until these days, the physicists have mostly skipped the test due to its difficulty. The new radiation delivery techniques such as VMAT require mechanically accurate treatment units. The current system could serve a feasible QA tool for all radiotherapy centers who want to fulfill the suggested requirements of IEC quality assurance recommendations.

EP-1295
Geometric accuracy of TomoTherapy Hi-Art system in target localization
M. Bucciolini¹, S. Pallotta¹, V. Reggiani¹, G. Simoncucci², G. Biti³
¹University of Florence, Medical Physics Unit - Dipartimento di Scienze Biomediche Sperimentali e Cliniche, Firenze, Italy
²AOU Careggi, Radiotherapy Unit, Firenze, Italy
³University of Florence, Radiotherapy Unit - Dipartimento di Scienze Biomediche Sperimentali e Cliniche, Firenze, Italy

Purpose/Objective: Geometrical accuracy is required in Tomotherapy treatments, especially when a single fraction of a very high radiation dose is delivered to a small target. This study focuses on image guidance using MVCT feature of TomoTherapy Hi-Art System. The purpose of this study was to assess the global accuracy of target localization process by evaluating the contribution of registration algorithm and MVCT slice thickness.

Materials and Methods: The accuracy in target localisation was estimated using an ad hoc designed plastic phantom with 8 glass spheres (GSs) inserted in known positions. The contribution of slice thickness and registration algorithm was evaluated by acquiring 24 MVCT scans of the phantom to which known shifts had been applied with respect to the planning image set. Corese medium and fine resolution were used. Registration results were compared against applied shifts. In order to test the global geometrical accuracy a Tomotherapy plan was prepared using 6 GSs as targets. The phantom was positioned on the Tomotherapy couch, with a gafchromic film inside, and the treatment was delivered. The gafchromic film was digitized and the dose distribution centroids relative to each GS were then evaluated and compared with correspondent GS known positions.

Results: The accuracy in target localization depends on MVCT image resolution and results are not comparable to voxel size. Better results were obtained when manual registration was used. Differences between automatic registration algorithms were also observed. Mean difference between dose distribution centroids and GS positions was less than 1mm.

Conclusions: Image guidance using MVCT feature of TomoTherapy Hi-Art System confirms that the system is capable to localize targets with voxel accuracy.