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

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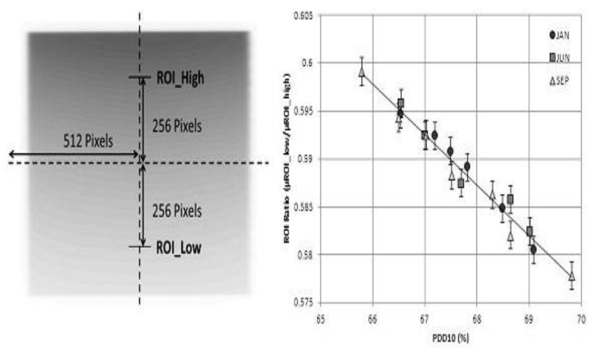
Purpose/Objective: To establish a method by which linac photon beam energy can be accurately measured through EPID image analysis with a view to clinical implementation as part of an automated linac QA routine.

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 (PDD_{10}) 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 ratios were plotted against the measured PDD_{10} 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 PDD_{10} 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 ± 0.24%.This is comparable to the uncertainty associated the measurement of PDD_{10} in the water-tank (±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 PDD_{10} in the water-tank, indicating that the measurement technique can provide a reliable metric of energy relative to the gold-standard (i.e. PDD_{10}). 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

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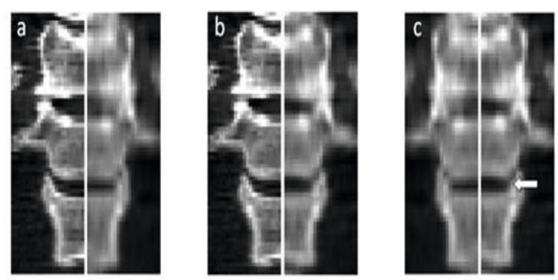
Purpose/Objective: Image-guidance navigation has become a frequently used technology that provides accurate radiation treatment by using 2D verification with DRR (Digital Reconstruction Radiograph) or 3D registration with planning CT images. The setup uncertainties can be minimized and the dose of normal 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 cm^3 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 z-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: ($AUC-AUC_{ref}$)/AUC_{ref}). 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. Figure1 a: 1mm vs. 3mm slice thickness; b: 1mm vs. 3mm slice thickness increment to 1mm; c: 3mm vs. 3mm slice thickness increment to1mm. 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

	m1	m2	m3	m5	m2_c	m3_c	m5_c
AUC(%)	0	-0.95	-1.92	-3.97	-0.60	-1.35	-2.54
penumbra	2.00	3.12	4.74	7.79	2.62	3.67	5.44



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

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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).

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 diameter 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
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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 localisation procedure 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 (manual and automatic) were tested by acquiring 24 MVCTscans of the phantom to which known shifts had been applied with respect to the planning image set. Corse 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 digitalized 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 to be 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.

EP-1296
Kilovoltage cone beam CT and planar megavoltage images in radiotherapy: dose and quality image
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Purpose/Objective: This study aims to evaluate two patient position verification techniques used in radiotherapy (kV cone beam CT - Elekta XVI and planar MV electronic portal imaging - Elekta Iview-GT) comparing the absorbed dose, effective dose and image quality obtained from each imaging modality.
Materials and Methods: The dose evaluation for the XVI system was performed using the CT Dose Profiler CT-SD16 diode (RTI Electronics AB) and two couples of head and body phantom, usually dedicated for CT dose measurements, attached together in order to obtain a 30 cm phantom length. Dose points in the longitudinal axis were acquired: 1) in air by positioning the detector at different distances off the isocenter, and 2) in water by placing the detector in the five different inserts and locations within the two modified phantoms. The $CTDI_{air}$and $CTDI_w$ were calculated for a range of various clinical acquisition protocols. Dose to organs and the effective dose was derived for anatomical regions from several sites (head, head and neck, chest, abdomen, and pelvis) using the ImPACT calculator with ICRP 103 tissue-weighting factors. Estimated doses for Iview-GT images were obtained from Philips Pinnacle^3 TPS. CT dose points from the modified head and body phantom were calculated, at the same positions as the XVI measurements, by planning in the TPS two orthogonal fields at 0° and 90° gantry angles with a 4 MV double exposure beam (10x10 and 20x20 cm^2) of 3 MU/exposure. The organs and the effective dose were evaluated in the TPS simulating patient treatment verification with the two orthogonal fields for the anatomical regions mentioned above. The mean dose received by each organ was derived from the DVH. The image quality was studied in terms of spatial resolution and percentage of noise to contrastratio (NCR%). Catphan-600 (PhantomLaboratory) and QC-3 (SeeDos Ltd) phantoms were used for the cone beam and planar images respectively. The spatial resolution was examined for the both imaging techniques comparing the lp/mm at MTF 10%, whereas NCR% was derived from the functions that relate the grey level and the linear attenuation coefficients from the various inserts present within the two phantoms.
Results: The results are shown in Table 1. The acquisition parameters, mean dose points evaluated in the head and body phantoms at the centre and periphery, the effective dose, resolution and NCR% are reported for the two imaging techniques.

Table 1		kV Cone Beam CT- Elekta XVI					Planar MV - Elekta Iview GT				
		HEAD	HEAD & NECK	CHEST	ABDOMEN	PELVIS	HEAD	HEAD & NECK	CHEST	ABDOMEN	PELVIS
Acquisition Parameters	kV	100		120		120	4 MV				
	mA per Frame	10		40		64	3 MU for each field				
	ms per Frame	10		40		40					
	Collimator	S20		M20		L20	Fields at each gantry angle : 10x10 and 20x20 cm^2				
	Filter	F0		F1		F1					
	Start and Stop Acquisition Angle (°)	-130 ÷ 70		-130 ÷ 70		-180 ÷ 180	Gantry angle: 0° and 90°				
	Frames (5.5 frames/s)	366		660		660					
	Reconstruction Preset	S20 - Med_Res		M20 - Med_Res		L20 - Med_Res					
	Matrix	1024x1024					1024x1024				
Dose	Phantom	Head		Body			Head		Body		
	Mean central points(mGy)	0.94 ± 0.11		14.99 ± 1.79		19.54 ± 2.31	82.5 ± 22.12		57.25 ± 15.58		
	Mean peripheral points(mGy)	1.04 ± 0.36		20.61 ± 2.66		24.32 ± 3.28	71.56 ± 19.41		40.38 ± 31.65		
Effective dose (mSv)		0.05	0.08	7	7.5	9.14	11.6	10.81	28.98	14.63	18.43
Quality Image	lp/mm (MTF 10%)	0.6		0.64		0.68	0.8				
	NCR%	6.22		1.54		1.2	0.58				

Conclusions: Evaluation of the mean dose shows central dose sparing with cone beam acquisition for all the clinical protocols, while there is not statistical difference between the two techniques for the peripheral dose of the body phantom. The effective dose varies for all the anatomical regions considered with the XVI imaging technique giving the lowest values. The quality image parameters are comparable with the exception of the two XVI head protocols. The NCR% value shows to be higher than Iview-GT images due to the different acquisition parameters.

EP-1297
CT metal artifact reduction in the pelvic area: clinical evaluation of a commercial product
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Purpose/Objective: To report on the CT number accuracy of the Metal Artifact Reduction for Orthopedic Implants (O-MAR), which is installed in our Brilliance Big Bore CT scanner (Philips Medical Systems, Cleveland, OH). The CT numbers in a phantom study of the pelvic area are evaluated in the presence of large metal objects, since accurate CT numbers are needed for adequate dose calculation in external beam radiotherapy treatment planning.
Materials and Methods: A TomoPhantom (TomoTherapy Inc., Madison, WI) was used to represent the pelvic area. This phantom (d = 300 mm) consists entirely of Solid Water (Gammex RMI, Middleton, WI) and contains 20 interchangeable rods (d = 28.5 mm, l = 70 mm), which allow for the introduction of inhomogeneities (see figure). Metallic hip prostheses were simulated with titanium rods (ρ = 4.51 g/cm3). Three