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Title:

Quality assurance of dosimetry calculation within radiotherapy planning systems in clinical practice, according to IAEA-TECDOC-1583

Prospective/Objective. Accurate commissioning of the treatment planning system is a critical part of the radiotherapy treatment planning process. Inaccuracy at the planning phase will affect not just one fraction, but all patient treatment planning courses. In this work the verification of point doses were performed at different regions of a heterogeneous phantom using 3D conformal Radiotherapy (3D-CRT) techniques as recommended by IAEA-TECDOC-1583 report.

The aim of this verification is to apply for the first time, this report on the Pinnacle3 at the Santa Chiara hospital, and gain the necessary knowledge to establish national audits in my home country.

Results. The CT-Density curves created show a difference 1.4% between the curve of the Gammex 467 using thorax protocol and the curve stored in Pinnacle3. When the Gammex was scanned using the monthly protocol, there was large difference in the areas of low density (maximum 24%) and in the areas of high density (maximum 68%), when compared to the Pinnacle3 curve. However, the monthly protocol is not used for TPS data, only for constancy evaluation. In clinical test cases, 315 data sets for the three algorithms and the three energies show that 301 data sets meet the agreement criteria based on IAEA-TECDOC-1583. 14 data sets fell outside the tolerance criteria. When analyzed based on energies, there was no data set that failed the tolerance for 10 MV, 8 data sets failed for 6 MV and 6 data sets failed for 4 MV. When analyzed based on algorithms, there were 3 data sets failed for CCC, 5 data sets failed for AD and 6 data sets failed for FAST.

Conclusion. The overall results show that 95.6% of data sets for the three energies and three algorithms met the criteria set by the IAEA-TECDOC-1583. The results revealed that the Pinnacle3 TPS calculations and Elekta Precise LINAC dose delivery for 3DCRT at Santa Chiara Hospital was generally within acceptable criteria according to IAEA-TECDOC-1583, and there was no major causes for concern. This study verified that CCC, AD and FAST were general well modelled in the TPS for high energy 10 MV. There was some fine tuning required for beams modelled with 6 MV and 4 MV, especially at heterogeneous regions containing high and low densities. It was also verified that CCC algorithm shows a better accuracy, compared to the AD and Fast algorithms. Deviations outside the agreement criteria

mostly occurred within test cases using beam modifiers and tangential beam passing through inhomogeneous materials.

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Title:

Validation of Robust Optimization Approach of VMAT Treatment Planning of Stereotactic Body Radiation Therapy of Lung Cancer

Prospective/Objective: To validate the robust optimization formalism to plan the VMAT SABRT of lung lesions using the Mid-ventilation approach by means of phantom simulations and measurements.

Materials and methods. To validate the robustness of the mid-ventilation approach, the quasar programmable respiratory motion management phantom (QPRMP) was used. The lung motion was mimicked by standard and customized homemade inserts containing films for an end to end test measurements, positioned inside it. The phantoms were simulated using a Toshiba 16 slice CT scanner, 4DCT datasets were acquired binning the respiratory cycle triggered by the Varian RPM system in ten phases. Real and perturbed patient RPM breathing signals were used to reproduce the effects of irregular breathing. The mid-ventilation phase, defined as the closer to the average lesion position, was used to plan the treatments with the Raystation TPS (version 8. A). Two plans were created using the geometric uncertainties derived by the non-linear Van Herk recipe applied to lung tissue: one relying on the standard static PTV concept, the other based on min-max robust optimization method that accounts directly for geometric uncertainties minimizing the optimizer cost-function in the worst-case scenario. For each plan, a 4D dose calculation was performed summing the deformable image registration (DIR) propagated dose recalculated on each phase on the reference Mid-ventilation phase. Treatment plans were compared between them and with standard ITV based procedures, to assess the advantages of robust optimization versus the standard static PTV concept and the effectiveness of the Mid-ventilation approach to manage tumor motion also in presence of marked breathing irregularities. Radiochromic films EBT3 irradiated inside the moving phantom were used to assess the accuracy of the robust optimized plans in the context of lung SABR.

Results. The Mid-ventilation approach in both cases allowed significant dose reduction to not target structures respect the standard ITV based method as expected. The robust optimized plan outperformed the standard static PTV based plan reducing the high dose spillage to not target structures and increasing the dose distribution conformity. The dose coverage to GTV resulted unaffected by robust optimization and was insensitive to the induced motion perturbations testifying the effectiveness of the method also in the presence of breathing irregularities. Film measurements showed optimal agreement between the 4D calculated dose by robust optimization and measured dose distribution with gamma

passing ratio of 91.6% (global, DD%=3, DTA=2mm, threshold 30%) demonstrating the optimal quality of the end to end process. Similar levels of agreement were found with the perturbed respiratory patterns.

Conclusion. The mid-ventilation approach outperforms the conventional PTV and ITV approach for lung SABR with online image guidance and is insensitive to breathing irregularities. The robust optimization resulted in an accurate and effective method to account for the geometric and dosimetric uncertainty for SABR inverse planning. As robust plans can better spare OARs located close to the irradiated volumes without compromising the dose coverage to targets, as this thesis demonstrated, they appear the technique of choice for the planning of SABR of lung lesions.

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Title:

Optimization of Time of Flight PET/CT Philips Ingenuity Scanner

Prospective/Objective: The increasing use of Whole-Body 18FDG PET/CT scanning in oncological patients asks optimization of acquisition/reconstruction parameters to improve lesion detectability with reasonable dose. The aim of this study was to optimize 18FDG Whole-Body studies of TOF PET/CT Philips Ingenuity scanner by using a multivariate approach to quantify how physical figures of merit related to image quality change with acquisition/reconstruction and patient-dependent parameters in a phantom experiment.

Materials and methods. The NEMA International Electrotechnical Commission (IEC) Body Phantom was used to evaluate contrast recovery coefficient (CRC), background variability (BV), and contrast-noise ratio (CNR) as a function of changing emission scan duration (ESD), activity concentration (AC), target internal diameter (ID), target-background activity ratio (TBR), and weight. A supplemental set of micro-hollow spheres (ID = 4.1, 4.7, 6.5, 8.1 mm) was positioned inside the phantom. The phantom was filled with 5.3 kBq/mL of 18F solution and the spheres with TBR of 21, 9, and 5 in 3 different sessions. Images were acquired at varying activity concentration of 5.0, 2.9, 2.0, 1.4, and 1.2 kBq/mL and images were reconstructed for ESD of 30, 45, 60, 75, 90, 120 and 151 s/bed with and without PSF correction with 1 iteration and 6 mm regularization. The parameters were all considered in simultaneous experiments and in a single analysis. Multiple linear regression methods were employed for the quantitative evaluation by using STATISTICA 6.0 software (Statsoft inc USA).

A preliminary clinical study was then performed on a small sample of patients to evaluate the impact of ESD and patient's BMI on the image noise and CNR. Thirty patients of different Body Mass Index (BMI) administered with 3 MBq/kg 18FDG with lesion-free liver underwent 18FDG PET/CT examination. The noise was evaluated at liver level and the CNR of lesions detected on the Whole-Body was evaluated. Both noise and CNR were analyzed with respect to the ESD.

Results. CRC depends only on sphere ID and on PSF application, while BV depends on sphere ID, ESD, AC and weight of the patient, in order of decreasing relevance. The ESD and AC resulted as the most significant predictors of CNR with comparable importance, followed by the weight of the patient and TBR of the lesion. PSF correction provided acceptable compromise between a slight enhancement in noise and an improved contrast recovery.

Although preliminary, the clinical study, confirmed CNR improvement and a decrease of CVB with increasing ESD.

Conclusion. The main finding of this study was the dependence of CNR on both ESD and AC with a similar importance. Thus, it will be equivalent to increase lesion detectability by adjusting the administered activity to the patient or the duration of PET bed. From radiation protection point of view, it is advisable to use the manufacturer suggested dose scheme while increasing the bed duration. To further increase lesions visualization, PSF correction could be applied, although with a slight increase in the noise, but without any Gibbs or edge artefacts.

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Title:

Dosimetric validation of VMAT and dynamic IMRT adapting AAPM TG-119 Benchmark Plans to 3D cylindrical phantoms in a Monte Carlo based TPS

Prospective/Objective: The AAPM – TG 119 presented the guidelines for a dosimetric study, to facilitate and ensure the accuracy after commissioning processes of TPSs for modulated techniques, using clinical tests with a cubic phantom made by PMMA slabs. The aim of the present study was focused on the validation of a new radiotherapy techniques within a Monte Carlo based TPS, for dIMRT and VMAT delivering, changing the shape of such cubic phantom to a cylindrical shaped ones. The benchmarks for the hospital were created in terms of confidence limits, using statistical methods given by the report.

Materials and methods. This work is divided in two main components: testing of the Monte Carlo dose calculation performance in Monaco TPS and evaluating the accuracy of the dose delivery system. Local treatment plans for dIMRT and VMAT were created following the guidelines purposed by the TG – 119, such as: structure sets, dose prescriptions/constraints, and, when possible, beam arrangements (dIMRT). The detectors systems used in this work, were a diodes array Delta[4] and a Matrix Phantom with a 0.125 cc ion chamber. These cylindrical shaped devices have the advantage to better simulate the patient shape. The dose was measured by two different approaches: composite dose distribution and absolute dose. For the dose distribution, the gamma criterion used were 3mm 3% and 2mm 2%. The TPS goals and the dose results were also compared with the task group institutions.

Results. The local dosimetrical plans for dIMRT and VMAT meet the Task Group goals except for C-Shape hard and Multitarget for VMAT. The techniques were compared by means of Conformity Index and Heterogeneity Index as well. The global gamma analysis from the overall results, show a passing rate of 98.9% and 94% using 3mm 3% and 2mm 2% respectively for VMAT, and 97.8% and 86.7% for dIMRT corresponding a confidence limit of 1.09 and 5.92 for VMAT, 2.17 and 13.29 for dIMRT. Regarding the absolute dose, a confidence limit of 0.052 and 0.056 were achieved for VMAT and IMRT individually from the overall results.

Conclusion. The dosimetrical validation for the upgraded clinical beams of dIMRT and VMAT was successfully performed. The methodology of the TG – 119 can be used in conjunction with cylindrical phantoms. The "in house" confidence limits values, created in this study could be used in frequent evaluations of correctness and integrity of: TPS, dose delivery systems and phantoms.

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Title:

Comparison of AAA (Anisotropic Analytic Algorithm) and AXB (Acuros-XB) calculation algorithms in heterogeneous medium with elementary geometry using radiochromic films

Prospective/Objective: Due to the increasing number of stereotactic body radiation therapy (SBRT) lung treatments and gated RT techniques performed, it is highly important to evaluate the accuracy of available treatment planning algorithms. The aim of the study was to measure dose distributions inside lung-like heterogeneous medium and compare them to dose distributions calculated by TPS algorithms (AAA and Acuros XB), in order to evaluate the impact of lateral scatter on their accuracy in simple geometries.

Materials and methods. Measurements were done inside heterogeneous phantoms containing solid water slabs in periphery and lung like material in the centre. Two materials were selected to simulate the lung with different standard deviation of CT numbers. Additionally, to observe the lateral scatter impact on dose calculations, the lung like material was removed and measurements were repeated with the Solid water phantom containing an air gap in the centre. Measurements were done using radiochromic films at different depths with constant beam parameters (6 MV photonbeam, SSD100cm, $10 \times 10 cm^2$ field size and 300MU for cork-based phantoms and 500 MU for solid water air phantom).

TPS calculations were carried out using the Eclipse treatment planning system and CT scans of the phantoms. Radiochromic films were scanned using FilmScan software and calibrated using FilmCal software. Differences between measured and calculated dose values were evaluated using PTW software VeriSoft.

Results. Beam profiles of measured dose and calculated dose in homogeneous lung phantom, inhomogeneous lung phantom and solid water phantom with air gap were obtained at different depths–1cm, 2cm, 3 cm, 5 cm and 6 cm in homogeneous lung phantom, at 2 cm and 6 cm in inhomogeneous lung phantom and at 2 cm in the phantom containing an air gap. Percentage differences and the mean difference between calculated and measured data were obtained.

Conclusion. The Acuros XB algorithm demonstrated better agreement with film measurements and therefore provided more accurate dose calculations compared to the AAA algorithm in heterogeneous medium with a simple geometry setup.

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Title:
Adaptive Radiotherapy in Head and Neck Cancer

Prospective/Objective: The purpose of this study was to evaluate the anatomical changes and related dosimetric effect using biweekly CBCT and deformable registration throughout the entire course of radiotherapy in a set of patients affected by head and neck cancer, in order to suggest to physician when replanning is necessary

Materials and methods. Nine Head and Neck patients, treated by VMAT and verified with bi-weekly CBCT for setup corrections, were reviewed retrospectively. A total of 9 planning CT and 102 acquired CBCT image sets were transferred from Pinnacle3 treatment planning system (TPS) to the MIM maestro DIR software. Each CBCT was used as reference image to which the planning CT was registered and the contours delineated for planning purposes were propagated. For both normal tissues and target volumes the deformed contours were visually evaluated by physician. Each deformed planning CT was transferred back into the TPS. The beam arrangements and optimization parameters of the initial treatment plan were copied to the deformed planning CT. The dose calculation module calculated the dose distribution from the copied treatment plan directly onto these deformed planning CT images. In this way for each deformed planning CT plan, dose volume histogram (DVH) was generated. Moreover, an accumulated DVH was generated by using deformable image registration and dose propagation. Targets and parotids volumes at each CBCT scan were compared to those of the planning CT. The dosimetric parameters including the near minimum dose (D98) to target, the volume of target receiving 95% and 99% of prescription dose were also compared. The mean dose to parotids from each deformed planning CT was compared to the mean dose from the initial planning CT. The actual delivered maximum dose to spinal cord, larynx and mandible was also compared to those in the planning CT.

Results. In the set of patients we considered, the mean volume of CTV, PTV1 (high dose planning target volume) and PTV2 (low dose planning target volume) decreased throughout the course of treatment by 19.14%, 14.42% and 14.43% respectively. However, the reduction in volume of target was not statistically significant. Compared to the initial planning, reduction in target coverage and a decrease in minimum dose to the target were observed. The minimum dose D98 decreased for PTV1 and PTV2 by 1.92Gy (p=0.017) and 6.46Gy (p=0.0091) respectively at the end treatment. Left and right parotids showed a mean reduction in volume of 31.1% (p=0.003) and 35.54% (p = 0.002) respectively. On average, the mean dose to the left and right

parotid increased by 2.22Gy and 1.95Gy (7.8% and 8.69%) respectively at the end of radiotherapy. However, this increase was not statistically significant. Dose accumulation using DIR demonstrated that the body shrinking during VMAT increased the dose of both parotids. The cumulative average mean dose to left and right parotids was respectively 105.29% and 117.48% of the planned mean dose. Delivered maximum dose to spinal cord, larynx and mandible demonstrated some significant differences when compared to the planning CT.

Conclusion. The use of CBCT and DIR could be useful to evaluate anatomical and dosimetrical changes in patients treated for head and neck cancer by VMAT. The DIR method exploited in this work could be adopted in offline verification and could help the physician to decide if replanning is necessary. In the set of patients we studied, volume variation in targets and OARs were pointed out during the course of treatment. This caused a discrepancy between the planned dose distribution and that obtained using DIR and dose recalculation. The random positional variability and gradual anatomical changes requires careful clinical monitoring and the frequent use of CBCT based image-guided radiation therapy, which should show variations. Determining an appropriate time point for replanning is critical to ensure that the planned dose to the targets and OARs can be delivered accurately throughout the entire treatment course. Although the use of routine replanning is probably not necessary, our findings suggest a significant benefit of replanning in appropriately selected patients. However, clinical prospective research and larger sample sizes are still needed to evaluate the best time point to replan.

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Title:

From 2D to 3D Image Guided Brachytherapy in carcinoma cervix

Prospective/Objective: The integration of cross-sectional imaging modalities (such as CT or MRI) into treatment planning for BT has allowed for the development of a three dimensional (3D) image based approach to prescribing and reporting. The aim of this study was evaluate the target coverage and dose received by OARs using different methods of assessment from 2D to 3D CT IGBT.

Materials and methods.: A retrospective study was done, fifty one (51) HDR BT plans from thirteen patients treated with 3D IGBT were re-evaluated using the recommended procedure from GYN GEC ESTRO working group for a transition from 2D to 3D CT IGBT. The clinical target volume (CTV) and OARs (bladder, rectum and sigmoid) were contoured on CT plans. Point A and ICRU 38 bladder and rectal points were defined on reconstructed CT images. All the plans were re-evaluated using Oncentra Brachy TPS which is based on TG43 algorithm. All the patients were treated with CT compatible Fletcher Applicator set and and Elekta Microselectron HDR After loader with a 192Ir source and underwent a post-implant pelvic CT scans with applicator in place. Firstly, 3D CT IGBT plans were used to evaluate how much doses point A and ICRU reference points receive when dose is prescribed in target volume. Secondly, the 3D CT IGBT

plans for patients treatment were reevaluated normalizing the dose to point A. lastly, the dose was prescribed to point A as in 2D based plans without any optimization to be in the same condition than traditional 2D plans but with volumetric dose calculations. Target volume coverage were checked comparing D90 (minimum dose received by 90% of the volume of CTV) and dose to point A. International Commission on Radiation Units and Measurement (ICRU) reference points for dose to OARs (bladder and Rectum) were evaluated in all the methods and compared to the doses received by 0.1cc and 2cc of these organs displayed by the Dose Volume Histograms (DVHs) in the 3D CT IGBT plans. The EBRT dose was given to a total of 45 Gy in 25 fractions and 50.4 Gy in 28 fractions. The total biologically weighted dose including EBRT was estimated using linear quadratic model.

Results. The CTV volume was 71±16 cc (range, 50.1 – 102.9cc). The results were given depending on the HDR fraction dose (6 and 7Gy) respectively. The mean percentage of coverage in 3D CT IGBT plans were 94±2% for 6Gy and 90.1±5% for 7Gy and the mean percentage of dose received by point A in these plans were 72±8.5% for 6Gy and 79±9.1% for 7Gy. For 3D CT IGBT plans normalized in point A, the mean percentage of coverage were

99.7±0.2% and 98±1% respectively and 99±0.9% and 98±2% for 2D point A based plans. The means D2cc and D0.1cc for bladder and rectum were lower than the corresponding ICRU points doses in both cases. All the differences were statistically significant.

Conclusion. Image guided brachytherapy (IGBT) for cervical cancer, using mainly 3D CT, is an evolving method, increasingly replacing the 2D approach based on conventional radiography. It has good conformity of target coverage and evaluation of doses to OARs. Prescribe the dose to the target volume spare more the OARs and IGBT help to respect the constraints adapting the dose in each fraction

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Title:

Quantitative analysis of PET acquisition performed by varying the acquisition/reconstruction settings: A corrective post-processing method

Prospective/Objective: The limited spatial resolution in positron emission tomography (PET) images leads to difficulties to measure correct uptake in tumors. In particular, this is the cause of the partial volume effects (PVE) and can lead to serious bias, especially for small tumors. Correct uptake values are essential for the correct quantification of a parameter widely used in clinical practice, i.e. the standardized-uptake-value (SUV). The aim of this research is to theoretically elaborate and experimentally evaluate a corrective method for PVE, alternative to the Recovery Coefficient (RC).

Materials and methods. In order to obtain the PSF of the PET system, we had to acquire the activity distribution from a point-like source. The acquisition was performed by GE MEDICAL SYSTEMS, DISCOVER 710. In the study, acquisition was performed using NON TOF and TOF correction, in order to analyze the effect of a change in the reconstruction algorithm on the PVE. For acquisition NEMA IEC Body Phantom, has been used.

The counts C of the six spheres has been evaluated inside spherical ROI with radius R equal to the real one using an ideal segmentation criteria. We obtained the x and y coordinates of the six spheres centers from the CT. After determining the center, we construct binary masks in which the voxels inside the ROI have value 1 while the voxels on the background have a value of 0. In order to be more precise in the application of the spherical mask on the acquired image we have done a rebinning. This procedure has been implemented in the MATLAB program and it Works. We did a voxel by voxel product between the finer image matrix and the binary mask, selecting only voxel in the ROI. We made the sum of these voxel obtaining the counts inside the spheres, which are representative of the activity in the ROI. From the different acquisition mode and time, we took the maximum value of counts, the mean value over a 1 cc inside each sphere and the average value on the total volume of each spheres. In order to recover the concentration values, we multiply the counts by the calibration factor normalizing to the volume. With this procedure, we obtain the respective SUVmax, SUVpeak and SUVmean.

Results. If the tracer is distributed uniformly throughout the VOI, then the SUV would be 1 everywhere. Any departure from 1 indicates a different distribution of the tracer in the VOI in comparison to that the rest of the body. There is no single way to assess the tumour uptake. SUV therefore

does not refer to a unique and standard definition. The ways the numerator and denominator are calculated can significantly affect the SUV estimate. We obtain the ratio between lesion SUV on the background SUV for theoretical and experimental (measurement) one. Thanks to data analysis, as it is visible from LBRmean, PVE effect is present for small dimension of ROI.

Conclusion. In this paper a method for the correction of the PVE in PET exams is presented. The method is based on the use of mathematical formula that describes the effect of the limited resolution of the system under reference conditions (homogeneous lesion on a constant background). We tested the effectiveness of the method by acquiring an IEC NEMA Phantom (6 spheres of different diameters) by varying acquisition time (noise) and reconstruction algorithms (TOF and NON-TOF iterative OSEM algorithm) at a fixed value of lesion-to-background ratio (LBR=4). The results obtained are very good: SUVmean corrected differs from the theoretical value less than 10% for all the spheres within the time of acquisition Is longer than 2 min (standard acquisition time of a PET exam). The limits and the applicability of this work to the clinical routine depend on the fact that our method was developed from reference conditions, different from those of acquisition of a patient.

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Title:

Implementation for the clinical use of an automated system for daily patient QA using log file and CBCT.using log file and CBCT.

Prospective/Objective: The aim of this study is to implement for clinical use SunCHECK^{TM} automated system for daily patient quality assurance and evaluate dose delivery using log file, CT and CBCT images in comparison with planned dose.

Materials and methods. Two modules from SunCHECK^{TM} platform were used: PerFRACTION^{TM} for daily dose calculation with collapsed cone superposition/convolution algorithm and DoseCHECK^{TM} for secondary independent dose calculation. Fourteen prostate VMAT plans were optimized and calculated using Monaco treatment planning system with Monte Carlo algorithm. The patients were treated using two matched Versa HD linear accelerators with Agility MLC. During each treatment fraction, CBCT was used for precise patient positioning and images were stored in MOSAIQ record and verify system. Log files, containing all linac information during delivery was created. After each fraction the CBCT images and log files were automatically retrieved and dose distribution was calculated. For a group of 7 patients, calculation in PerFRACTION^{TM} was performed using a beam model provided by SunCHECK^{TM}, while for other 7 patients, a customized beam model based on adjustment required by the medical physics was implemented. The quantitative evaluation of dose distributions was done using the gamma index analysis with 3%/3mm criteria and comparison of DVH-based metrics.

Results. In total 1002 dose distribution was calculated and compared. During DoseCHECK^{TM}, the mean gamma passing rate for all prostate cases was superior to 99% with 3%/3mm criteria and average dose deviation of DVH metrics was 0.79±2.2% and 0.13±1.1% for general and customized beam model respectively. For daily patient QA, the overall gamma passing rate for dose distribution calculated on CT images was 98.9% (ranged from 97.7% to 100%) and 99.5% (ranged from 97.3% to 99.9%) using general and customised beam model respectively, while calculated on CBCT images was 97.4% (ranged from 93.6% to 99.8%) and 99.0% (ranged from 95.6% to 100%) . The average dose deviation for all DVH metrics was lower than 3% and 1% calculated on CT images using general and customised beam model respectively and lower than 4% and 2 % calculated on CBCT.

Conclusion. The automated system for daily patient QA which was implemented for the clinical use is innovative QA methods provide effective and efficient

approach in verifying delivery accuracy in terms of gantry, collimator, jaws, MLCs. position and delivered MUs. According to result of performed daily QA, all patients were treated with recommended accuracy. The confidence limit for Gamma passing rate with 3%/3mm criteria for daily QA and median dose deviation was suggested. CBCT images for daily QA can give information about interfraction patient anatomy changes and patient positioning. After 3rd week of treatment the increasing of dose deviation was observed. The log file and CBCT or CT images-based dose calculation together with specific QA program for the dynamic performance of the MLC and accuracy of log file recorder could replace conventional QA methods.

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Title:

Electron beam commissioning of an Elekta Synergy linear accelerator

Prospective/Objective: The project was aimed at commissioning of electron beam of an Elekta Synergy linear accelerator at Mauriziano Hospital in Turin, Radiotherapy Department.

Materials and methods. Commissioning of electron beam has been carried out following the recommendations of AAPM TG-106 for appropriate detector selection, measurement techniques, etc., and the measurements required for RayStation TPS commissioning have been realized.

Commissioned energies of electron beam were 4, 6, 9, 12, 15 MeV generated by the Elekta Synergy linear accelerator (linac). All the measurements were performed at collimator and gantry zero using: 3D- sun nuclear water tank phantom filled of water except for the measurement of air fluence factor OFair where it was empty, and two detectors (diode, SemiFlex ionization chamber type-31010).

The measurements required to model electron beams in the treatment planning system RayStation (which use Monte Carlo dose calculation algorithm for electrons) for each energy were: Depth dose in water with (6 × 6 cm2, 10 × 10 cm2, 14 × 14 cm2, 20 × 20 cm2 and 25 × 25 cm2 applicators) and without applicators at 100 cm source-to-surface distance (SSD), profiles both in-line and cross-line with and without applicators, air fluence factor OFair at SDD=75cm and 95 cm with 8×8, 8×20, 8×30 and 30×30 cm2 field size, and applicator water dosimetry calibration data (at fixed number of monitor units) as specified in the commissioning manual. Sun nuclear dosimetry software was used to analyze data collected.

Result. From electron PDD data obtained, the depth of dose maximum for 4 MeV,6 MeV, 9 MeV ,12 MeV and 15 MeV was 0.93 cm, 1.27 cm ,1.88 cm, 2.93 cm, 3.40 cm respectively. The differences in the surface area of the PDDs were of the order of 6%. The flatness and symmetry of scanned profiles for each energy were not exceeding 2%.

Conclusion The results obtained for dosimetric data (percentage depth dose, beam profiles, output factor applicator water dosimetry calibration data) are within the tolerances recommended from published research, the beams of linac meet the specifications to be adequately used clinically for patient treatment.

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Title:

A comparative study of two treatment planning systems for IMRT optimization

Prospective/Objective: The Eclipse™ treatment planning system is in routine use at Istituto Nazionale Tumori Regina Elena, Italy, to generate individual treatment plans. The institute has recently purchased the research version of the Pinnacle3 treatment planning system. The Pinnacle[3] treatment planning system incorporates the Auto-Planning® optimizer that automates many processes of the manual optimization. The aim of this study is to compare the plan quality among plans manually optimized both in EclipseTM and Pinnacle3, and plans generated by the Pinnacle3 Auto-Planning R engine.

Materials and methods. Nine cases including three breast, three head and neck, and three prostate were selected for this study. IMRT plans were generated using the FiF technique for the breast cases, fixed gantry inverse planning IMRT for the head and neck cases and VMAT for the prostate cases. Two plans were manually optimized for each case: the first plan was optimized using EclipseTM and the second plan was optimized using Pinnacle3. A third plan was generated using Pinnacle's Auto-Planning® optimizer for the prostate and the head and neck cases. The target coverage, dose homogeneity, dose conformity, organ at risk sparing and delivery efficiency were evaluated. The PQM% and the APQM% scores calculated using the plan quality algorithm in the PlanIQ™ software provided a measure of the overall achieved plan quality of the plans. Statistical analyses were performed using paired t-tests with a level of significance at 5%.

Results. There were no significant differences between the FiF plans created in EclipseTM and Pinnacle3 treatment planning systems. Similar DVHs where obtained from the IMRT plans. On average dose conformity was better in the EclipseTM IMRT plans but with significantly increased monitor units. The Auto-Planning® IMRT plans provided better sparing of the OARs. The PQM% scores were slightly higher in the Eclipse™ IMRT plans but the differences with the manual Pinnacle3 and the Auto-Planning® IMRT plans were not significant. VMAT plans optimized with Auto-Planning® had better target coverage, dose homogeneity, OAR sparing, and higher PQM% scores than the manually optimized EclipseTM and Pinnacle3 VMAT plans. The monitor units obtained from EclipseTM, Pinnacle[3] manual planning and Auto-Planning® VMAT optimization were comparable.

Conclusions. While the optimization algorithms, optimization tools and dose computation algorithms differ in

the Eclipse™ and Pinnacle³ treatment planning systems, IMRT plans of similar quality can be created. Auto-Planning®, with manual intervention, could increase the quality of IMRT and VMAT plans. Auto-Planning® could be used as a starting point. Manual improvements to the dose distribution could then be made starting from the Auto-Planning® solution.

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Title:

An artificial neural network model for treatment plan verification of vaginal cuff HDR Brachytherapy

Prospective/Objective: To develop an artificial neural network (ANN) model able to predict the expected total reference air-kerma (TRAK) of HDR brachytherapy (BT) plans for endometrial cancer patients, to be used as a quality assurance (QA) tool for treatment plan verification.

Materials and methods. 182 vaginal cuff postoperative HDR BT treatments of patients with endometrial cancer delivered at the Fondazione IRCCS Istituto Nazionale dei Tumori between January 2018 and July 2019 were considered. Patients were treated according to various dose prescriptions (i.e., between 500 and 700 cGy), fractionation schedules, applicator types (i.e, cylindrical single-channel and multichannel vaginal applicators), and applicator diameters (i.e., 25 and 30 mm). TRAK, target volume (Vtarget), and the percentage loading of the central catheter (%CCL) with respect to peripheral ones (where available) were collected. Since the TRAK is linearly correlated with the dose, it was normalized to prescribed dose (nTRAK) to avoid any bias related to the delivered dose. A multilayer-perceptron regression ANN was trained to predict the nTRAK starting from Vtarget, %CCL and the applicator diameter. To overcome data overfitting, a simplified ANN architecture with up to three hidden neurons was chosen and the training was

performed according to the early stopping method. The dataset was randomly split into train (120), verify (31) and test (31)

Results. The resulting Pearson R-correlations between the actual nTRAKs and those predicted by the obtained ANN were 0.94, 0.95 and 0.94 for train, verify and test cases, respectively. The performance of the ANN was higher when compared to the linear regression of data, stratified according to the applicator diameter (i.e., R=0.92 and R=0.89 for the 25-mm and the 30-mm applicator, respectively). 13.3%, 6.5% and 3.2% of the studied treatment plans belonging to the train, verify and test groups, respectively, showed a relative difference between predicted and actual nTRAK values greater than 10%.

Conclusion. The TRAK in vaginal cuff HDR BT treatments can be accurately predicted with an ANN model and can therefore be used as a possible QA parameter to check treatment plan reasonableness. A deviation greater than 10% between predicted and actual nTRAK values could constitute a possible action level for a thorough investigation of the treatment plan. The proposed methodology can in principle be extended to other BT treatments.

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Title:

Implementation of a 3T MRI scanner dedicated to research: Commissioning and Quality assurance program establishment.

Prospective/Objective: To implement a commissioning protocol for a MRI system dedicated to neuroimaging, supplied by quality controls on subsystem components and image quality assurance in a multi-channel head coil. Establishing a benchmark data from acquisitions series on different advanced imaging techniques following international guidelines.

Materials and methods. The MRI system characterized was a Philips Ingenia CX 3T, 60 cm bore diameter, with the main signal receiver, a 32 channels dStream head coil. The commissioning protocol established was separated in quality control and image quality assurance. The quality control includes the assessment in subsystems, homogeneity of the main magnetic field and the coil elements performance, in a single slice reconstruction from an elliptical phantom, provided by Philips. The image quality assurance was performed using three phantoms (i.e. AIFM, PIQT and ACR). The AIFM (Italian Working group) phantom in advance techniques on MRI (i.e. MRS, DWI and fMRI). The PIQT phantom in periodical controls by Philips on spin echo and fast field echo. The ACR (American College of Radiology) phantom for clinical accreditation on weighted T1 spin echo. The assessment metrics were taken from international guidelines (i.e.

AAPM, ACR, AIFM, FBIRN and NEMA). Afterward the set of images acquisitions were processed in Matlab (R2017b) from developed custom codes included in an interface. The benchmark data were represented by the mean value and the standard deviation of a normal distribution, from 5 measurements repetition on each metric and compared with the references recommended on the guidelines.

Results. The benchmark produced during the commissioning shown to be in agreement in the 5% significance level (t-test) with the reference data taken from the guidelines. In the cases were not possible to find studies under similar conditions, PIQT phantom analysis and FBIRN in the AIFM phantom, was produced a discussion according the expected results for a correct behavior of the MRI system under study.

Conclusion. The commissioning protocol provided includes three main test types, identified as: General Systems, Quality Controls and Quality Assurance. The metrics analyzed were comparable with the guidelines recommendations for a stable MRI 3T, ensuring the correct functionality in the scanner for clinical use. For the implementation in a routine protocol is recommended a study in terms of the time production and levels of confidence found.
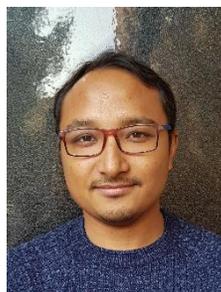
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Title:

Commissioning and Type Testing of RADOS RE2000A and RadPro LiF:MCP Dosimetry System

Prospective/Objective: Replace the 12 years old Thermo 6600Plus dosimetry system with a new automated RADOS RE2000A reader and RadPro LiF:MCP dosimetry system. General public together with hospital staffs, students and trainees working in an area where there is a risk of being exposed to ionizing radiation, should be in a safer environment as recommended by the IAEA Basic Safety Standard Series. For this conformity, proper radiation monitoring should be established.

Materials and methods. A new RADOS RE2000A reader system from MIRION Inc. was acquired with the LiF:MCP chips provided by RadPro. LiF:MCP (Radpro specific commercial name of LiF:Mg,Cu,P material) is mostly used thermo-luminescent crystal having dosimetric glow curve peak around 220 °C. It has the advantage of being linear up to 10 Gy, more sensitive with respect to previous LiF:Mg,Ti (from internal tests with previous system about 10 times) and negligible fading. The reader can identify the slides, which are assigned with unique serial number and a binary bar code, through its inbuilt barcode scanner and data entry. The reader can process automatically up to 200 dosimeter cards or 800 single TL-elements at one load. The pre-heat, measurement and anneal cycles are programmable through the software. In addition to this, the software can be fed with element-sensitivity correction, background subtraction and pre- and post-calibration capability. For calibrations and angular dependence purposes, set of selected chips were irradiated in Secondary Standard Dosimetry Laboratory (SSDL) with different energies from X-ray tube, Cs-137 and Co-60. For type testing, anyhow, being not possible to make all testes in SSDL, irradiations were done in the hospital environment with inhouse calibrated X-ray tube and RadPro Irradiator with Sr-90 source. A group of 20 cards were selected as a reference calibration cards because they showed less fluctuations within 5% following standard irradiation with 90Sr source and were sent to SSDL for the reference irradiation of 500 µSv with different energies, at different angles and on slab or pillar mimicking body and wrist of a person. Calibration was made for Hp(10), Hp(0.07) slab and Hp(0.07) pillar operational quantities; calibration with H*(10) was deduced from the one for Hp(10) based on previous obtained data. Individual element correction factor (SIR) were evaluated for each dosimeter. All the tests recommended by the European Commission Radiation Protection 160 like additivity, fading, linearity, reproducibility, sensitivity, energy and angular dependence were checked. Simplified IEC 62387 standards were followed to

estimate both the compliance with limits and the uncertainty for each evaluation.

Results. The distribution of the SIR value of all the TLD chips were not Gaussian however the repeatability of the SIR values were within 2%. The additivity response of the dosimeters was between 0.99 and 1.01. The sensitivity was evaluated with three processes, with a simple 2σ, a box plot (Upper Limit-Median) and Hirnings method and all of them resulted in quite near values of around 12 μSv. The signals were found to fade to about 11% in 10 weeks and the crystals were found to be linear below 1 Gy dose corresponding to the reader environment. The crystals were found to be reproducible within 6%. Considering 137Cs as the standard beam energy, we found maximum of 20% variation with ISO beam quality L1, that is of energy of 45 keV while this variation decreases with increasing radiation energy. Angular dependence was checked for 3 energies at two angles 0° and 60°. The angular dependence was highest at around 31% for Hp(10) cards for the ISO L4 beam quality, of energy 104 keV.

Conclusion. All the results agreed with requirements from the IEC 62387 standards and the new dosimetry system is all capable for efficient personal monitoring of the public in addition to staffs, students and trainees who are at risk of being exposed to ionizing radiation.

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Title:

Independent verification of selected dosimetric and geometric parameters of Machine Performance Check on two TrueBeam linear accelerators.

Prospective/Objective: Provide an assessment of selected dosimetric and geometric checks on two TrueBeam linear accelerators and compare the outcomes against MPC tool.

Materials and methods. Weekly absolute dose measurements in RW3 solid water phantom were conducted with a secondary dosimetric system (SS) using Farmer ionization chamber and PTW's Unidose electrometer for the commissioned photon energies. Beam output change measured with MPC and SS was analysed using student's t-test tool. Beam center shift assessments were performed on the EPID at SSD 130cm with 6MV for 8 collimator rotations. A Matlab script evaluated the maximum distance of the MV image(as detected from the edges)at source axis distance from the beam central axis (BCA)position. Radiation treatment isocenter size with 6MV, 10MV and 6FFF was evaluated on the EPID using Winston-Lutz test performed with Brainlab's ball bearing tool fixed on a mask base insert, for 8 gantry angles with collimator 90º and 270º. A Matlab script evaluated the maximum distance between the BCA and imaging isocenter (identified as the center of the sphere).Rotation induced couch shift was assessed using EBT3 Gafchromic film placed on the couch at SSD 100cm, for 5 couch rotations with collimator 240°, 0° and 120°.A Matlab script automatically calculated the projection of the BCA position on the film for five couch angles. The mean distance between the projected BCA position on the film and the couch rotation axis was assumed to quantify the induced couch shift. Collimator rotation offset was evaluated on the EPID for five collimator rotations at zero gantry and MV images analysed using ImageJ.

Results. The mean beam output change acquired for all energies with MPC and the SS were within ±2% tolerance because the TrueBeam linacs were calibrated whenever the output approached this limit. A good agreement between MPC and SS was realized. The mean difference in beam center shift measured with MPC and EPID was 0.02mm ±0.02 and 0.13mm ±0.02 on TB STX and TB respectively. The mean beam center shifts measured with MPC and EPID were within ±0.5mm tolerance limit. The mean difference in isocenter size measured with MPC and WL for 6MV was -0.02mm ±0.03 and -0.05mm ±0.02 on TB STX and TB respectively. TB STX showed a mean WL isocenter size of 0.29mm ±0.02 and 0.27mm ±0.03 for 10MV and 6 FFF respectively, while TB recorded 0.33mm ±0.01 and 0.36mm ±0.02, all within ±0.5mm

tolerance. The mean difference in the rotation induced couch shift measured with MPC and film was 0.02mm ±0.02 and 0.04mm ±0.04 on TB STX and TB respectively. The mean difference in the collimator rotation offset attained with MPC and EPID was -0.03º±0.03º and 0.04º±0.03º on TB STX and TB respectively, all within ±0.5º tolerance

Conclusion. MPC is a suitable tool for daily QA since the overall procedure is very fast and less cumbersome. However, departments maintaining and implementing a robust QA programme alongside MPC tool for an independent assessment is fundamental.

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Title:

Determination of small field correction factors in LINAC-based stereotactic radiosurgery through the application of the Alfonso formalism

Prospective/Objective: As part of the quality control program for stereotactic treatments at the Santa Chiara hospital Trento, a Pinpoint (PTW-31016) ionization chamber in conjunction with a Real Water head and neck phantom (PTW-T40015), is used to perform pre-treatment dosimetric verifications. The correction factors applied to these measurements are those published for small static fields, as there are none that exists for composite fields using a similar setup and equipment. It is the objective of this work, to determine chamber correction factors $k_{Q_{fs},Q}^{f_{fs},f_{ref}}$ and $k_{Q_{pcsr},Q}^{f_{pcsr},f_{ref}}$ for a Pinpoint (PTW-31016) chamber in small static and composite fields. These factors are to be determined using Real Water phantoms for 6MV photon fields as small as 10mm^2.

Materials and methods. EBT3 films and TLD-100 chips were chosen as reference dosimeters due to their availably, established calibration methods, and suitability for accurate dosimetry in small fields.[1] Following the optimization of these dosimeters using tried and tested techniques,[2–5] calibrations were carried out by exposure to augmented doses ranging from 45 to 1090cGy. Exposures were carried out with RW3 slabs using 6MV photon beams from an Elekta

Agility™ LINAC. A PTW-31016 Pinpoint ionization chamber was characterized for small field dosimetry and true point of measurement with respect to the housing phantoms as well polarity and saturation factors determined. Field output factors and static field chamber correction factors $(k_{Q_{fs},Q}^{f_{fs},f_{ref}})$ for the Pinpoint chamber were evaluated using RW3 slabs. These results were compared to TRS-483 data as a check of consistency. Plan class specific correction factors $(k_{Q_{pcsr},Q}^{f_{pcsr},f_{ref}})$ for the same chamber were determined using composite fields created from homogenous beams of fixed widths and angles. The $k_{Q_{fs},Q}^{f_{fs},f_{ref}}$ data and the $k_{Q_{pcsr},Q}^{f_{pcsr},f_{ref}}$ data were used to create fitted models of Pinpoint correction factors, which were tested using composite fields comprised of modulated beams.

Results. The chamber correction factors assessed with both the Gaf and TLDs were compared with the data published in TRS-483. It was seen that the correction factors $k_{Q_{fs},Q}^{f_{fs},f_{ref}}$ determined with the EBT3 showed an excellent agreement with that of the TRS-483 data, and validated its use for acquiring similar factors in composite fields. TLDs produced undesirable results, due primarily to the lack of appropriate phantoms within which they could be held. Corrections factors

$k_{Q_{pcsr},Q}^{f_{pcsr},f_{ref}}$ acquired for similar field sizes increased significantly at 20mm and lower. Both models were tested with composite fields and results showed that for unmodulated fields, factors derived with $k_{Q_{fs},Q}^{f_{fs},f_{ref}}$ fitting were predicted to within 1% of the measured values for field sizes greater than 20mm². Beyond this point errors in prediction increased up to 10%. For modulated beams, factors derived with $k_{Q_{fs},Q}^{f_{fs},f_{ref}}$ were predicted to within 3% on average. Correction factors projected with the homogenous composite field fitting $k_{Q_{pcsr},Q}^{f_{pcsr},f_{ref}}$, were accurately predicted to within 1% of the measured value for both modulated and unmodulated beams.

Conclusions. EBT3 films are a good option as reference detectors in small photon fields if the necessary precautions are taken to reduce uncertainties. Under clinical conditions, the application of chamber correction factors acquired from static fields may result in dosimetric inaccuracies. These inaccuracies are more pronounced for field sizes lower than 20mm², especially when there is a high degree of modulation or inhomogeneity dose over the chamber associated with the plan. To improve the dosimetry of ionization chambers measurements under clinical conditions, it is recommended to use chamber correction factors derived, from fields more closely comparable to that of the clinical situation.

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Title:

Comparison between free breath and deep inspiration breath hold techniques and advantages for left breast cancer in radiotherapy

Prospective/Objective: Several studies have demonstrated that the deep inspiration breath hold (DIBH) technique of radiotherapy for the patients of left-sided breast cancer reduce the cardiac dose more than free breath technique. In dosimetric comparison, the objective is the comparison the dose coverage of PTV (Planning target volume) and the comparison the OARs (organs at risk) respect their constrain between 3DCRT (Three Dimensional Conformal Radiotherapy) and IMRT (Intensity Modulated Radiotherapy), and between FB and DIBH. Then, to find some parameters to divide patients to choose either FB or DIBH which depends on free slot of LINAC (Linear Accelerator). And also, to find out the difference of dose distribution between with & without interruption of DIBH technique for DQA (Delivery Quality Assurance) of IMRT by using Delta^4 phantom+. Another aim is to evaluate the setup margin for DIBH and also find some criteria to apply the DIBH technique according to patient's ability.

Materials and methods. There was studied total 26 patients of left breast cancer at CRO (Centro di Riferimento Oncologico), Aviano. The simulation of FB and DIBH were done by Toshiba Aquilion 16 CT (Computed Tomography) simulator with RPM (Real-time Position Management) system. After contouring the PTV and OARs and prescribed the dose with constrains by physician, then the physicist planed FB_3DCRT, DIBH_3DCRT, FB_IMRT and DIBH_IMRT for each patient. After evaluation of these plan and performed DQA test by Delta^4 phantom+, DIBH_IMRT plan was executed by Varian-TrueBeam LINAC included RPM system. We performed the additional QC (Quality Control) of gating camera of TureBeam and also the DQA with & without interruption of DIBH technique of IMRT using Delta^4 phantom+. Moreover, we measured the setup margin by Van Herk's formula and compared with residual uncertainties.

Results. Between FB and DIBH image acquisition, there are 15 cm3 (~2.5%) (p<0.01) difference of PTV volume and the average minimum distance between LAD (Left Anterior Descending artery) and PTV is 1.25 cm in slice view and 1.43 cm in BEV (p<0.00) which indicate significant difference between both images. In dosimetric comparison, in DIBH technique, 90% and 95% dose coverage of PTV are significant better (p<0.05) and dose of all OARs is more satisfied than FB technique. But, comparison between modalities, it varies for each OAR. At the 1.6 cm distance between LAD and PTV in slice view of FB images, there is no significant difference of PTV coverage for all modalities and techniques.

Therefore, we can choose either FB or DIBH technique depends on free slot of LINAC included DIBH equipment. Because, OARs respected the constrain for both techniques. For DIBH_IMRT, the setup margin by Van Herk's formula is calculated on average 0.9 cm for 90% CI (Confidence Interval). Total residual uncertainty was calculated as 0.7 cm when online correction was applied. Therefore, there is possibility to minimize these setup margin 0.2 cm more for online correction in DIBH. The average duration of DIBH per respiration = 19 ± 4 sec while CT scan required minimum 19 sec. So, minimum 19sec of BH is criteria to choose patient to apply DIBH. The difference of dose distribution between with & without interruption of DIBH technique for DQA of IMRT by using Delta[4] phantom+ is on average 0.9 mGy which is negligible and it ensures that the interruption of treatment delivery by LINAC isn't significant.

Conclusion. DIBH advantages in significant for dose coverage and spare OARs for 3DCRT and IMRT. But, to apply DIBH technique depends on patient's ability and free slot of LINAC with RPM. Moreover, treatment delivery for DIBH with interruption is not significant difference and there is option to minimize setup margin for DIBH by using visual coaching.

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Title:

Cross calibration with different dosimeters in Electron Fields

Prospective/Objective: The objective of this study is to obtain for the Parallel plate Ion chambers in electron beam as a second check we compared the absorbed dose calculated with this factor for different electron energies with absorbed dose measured using $N_{D,W}(60_{Co})$ for the same chambers and using as reference the farmer chamber with $N_{D,W}(60_{Co})$ factor.

Materials and methods. Clinac 2100 CD linear accelerator with photons and electron beams, one cylindrical chambers and one parallel-plate ionization chamber were utilized. PTW Unidos electrometer and water phantom were also used.

Results. For the plane-parallel chamber the calibration factor 60_{Co} provided was also used. A direct comparison of absorbed dose values was performed. The maximum difference between the dose calculated by $N_{D,W}(60_{Co})$ (Advanced Markus and the calculated by $N_{D,W}$ (cross calibration) (Advanced Markus) it is 1% in low energy (6 MeV). The maximum difference between the dose calculated by $N_{D,W}(60_{Co})$ (farmer chamber) and $N_{D,W}$ (cross calibration) went of 0.3 %.

Conclusions. The calibration of PPIC cameras in electron fields using the Farmer camera as a reference is a good option and this can be done in the local department, so cross calibration could be added as part of the tasks of the local medical physicist

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Title:

Evaluating a Daily Quality Assurance programme for the Varian DHX Clinac Linear Accelerator at Azienda Ospedale Universita Pisana (AOUP) using the On-board Electronic Portal Imaging Device (EPID)

Prospective/Objective: The Portal Vision aS500 EPID measurements of the CAX, flatness and symmetry will be used to determine stability of the device in order to determine the ability to utilise the aS500 EPID as a tool for daily quality assurance check for the Varian DHX Clinac at the radiotherapy unit at Azienda Ospedale Univesitas Pisana.

Materials and methods. The materials used are the combined Portal Vision aS500 EPID and Sun Nuclear EPIDose software and the PTW QuickCheck device which are tools used for pre-treatment dosimetry QA and daily LINAC output checks respectively. The image acquisitions obtained by the EPID will be analysed by the Sun Nuclear EPIDose software to obtain the CAX dose, radial and transverse flatness and symmetries. Flood field calibration was only performed for the 6MV energy and not the 15 MV energy. This was done on purpose to observe how doing flood field calibration of one energy on the EPID would effect changes and compare that with the energy with no flood field (FF) calibrations. These measurements will be compared against the PTW QuickCheck to analyse the progression stability of the devices. The EPID and the QuickCheck use different algorithms to process the data, in order to ensure that the comparison of the data is compared with greater similarity, the raw data from the PTW QuickCheck will be calculated using the EPID algorithms to obtain consistency in comparison of the data.

Results. The CAX measurement as time progressed are not influenced by the Flood Field (FF) calibration. Throughout the course of data collection, it was observed that the 6MV flatness was more unstable than the 15MV flatness and for both energies the transverse flatness was more unstable than the radial flatness. It was observed from the data collected that doing flood field (FF) calibrations affect the flatness of the profiles as expected. During the dates when flood field calibration was performed for the 6MV energy, the profiles deviated from the baseline. This was not observed for the 15 MV where no FF calibration was made for the same date. The changes in the 15 MV data was due to changes in LINAC symmetry that consequently resulted in the change in flatness. This was checked through the measurements done with SLA48 which is our reference detector for profile constancy at AOUP. The analysis showed us that the data collected for symmetry are affected by flood field (FF) calibrations much more than the flatness. This is due to intrinsic LINAC changes in symmetry. The

changes in the symmetry were in fact observed even in the 15MV measurement where no flood field calibration was performed. This was again confirmed with the measurements done with the SLA48 which we needed once to readjust the LINAC symmetry to the baseline value.

Conclusion. In conclusion we can assess that the combined aS500 Varian EPID and Sun Nuclear EPIDose software can be used for daily dosimetric quality assurance of the AOUP DHX Varian LINAC. This is true in particular for CAX dose measurement. In fact, this system is reliable for relative measurements of the output provided that we fix the baseline values and set a tolerance threshold. For daily measurements of flatness and symmetry we can say that, provided that flood field (FF) calibrations are done one time only and immediately after big maintenance of the LINAC in order to set correctly the baseline values, this system could be a quick and accurate tool to guaranty linac dosimetric stability in a more accurate way than typical daily quality assurance instruments (e.g. QuickCheck) do.

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Title:

Accuracy comparison between optical and radiographic in-room imaging systems on a LINAC dedicated for SRS/SBRT

Prospective/Objective: In modern radiotherapy patient setup and intrafractional motion control is the key of a successful treatment. To improve treatment efficiency, Image Guided Radiation Therapy (IGRT) systems are used in clinical practice. Over the years IGRT systems have developed rapidly and currently there are several approaches: Optical (VisionRT AlignRT™) or radiographic (CBCT, OBI, EPID, Brainlab ExacTrac™). In order to choose the suitable imaging system, it is necessary to evaluate their accuracy. Therefore, the aim of work is to compare different IGRT systems, in order to evaluate final delivered dose to the clinical target volume (CTV).

Materials and methods. Accuracy evaluation was performed in two parts: phantom based evaluation for geometric instrumental accuracy and simulated evaluation in TPS for the accuracy related to the chosen workflow device dependent. For phantom based evaluation, different imaging systems (OBI, EPID, CBCT, ExacTrac™ and AlignRT™) were tested using Cube phantom. Cube phantom was positioned in isocenter of Varian TrueBeam STx™ linac and suggested couch shift was registered for each imaging system. Secondly, the possible CTV shift was simulated in TPS to evaluate the inaccuracy of imaging system effect on dose distribution to CTV. AlignRT was evaluated with shifting only CTV and ExacTrac was evaluated by shifting CTV together with isocenter. 3 prostate patients were selected for this study and changes in mean, maximum, minimum and D98% dose in CTV were compared with original dose without CTV or isocenter shift.

Results. In phantom study AlignRT™ and ExacTrac™ required shift of treatment couch was ≤ 0.6 mm in translational directions and ≤0.7° in rotational angles, while CBCT required ≤0.2 mm in translational direction and ≤ 0.2° in rotational angels, OBI and EPID have required ≤ 0.9 mm in translational directions and ≤ 1.2° in rotational angles. In evaluation with TPS there was no significant change on dose distribution to the CTV, while in some particular case have fluctuation but, overall, mean values was very near to the original plan values per each parameter (MIN; MAX; Mean; D98%[%]). To evaluate system in general, average difference between 3 patient data was calculated. Maximum difference was found in Max (maximum dose to CTV) and it was -0.35% relative to the prescription of 67.5 Gy for ExacTrac™ in-room imaging system.

Conclusions. Comparison of examined imaging systems shows that, takin care of high accuracy traceability of each phase of

calibration process for all system, instrumental accuracy evaluation in terms of deviation relative to the LINAC reference systems (axes and isocenter) is excellent for all systems and leftover inaccuracy is lower than 0.6 mm(along axes) and lower than 0.7 ° (around each axes). Simulated virtual evaluation using TPS was proposed as an open question on the impact on the overall accuracy of the devices. this kind of treatment accuracy was evaluated in terms of robustness of delivered dose to the clinical target volume (CTV). such robustness was evaluated in relation to the possible sources of residual error in the positioning and related to inner organ motion or patient surface random or breathing related movement. The TPS simulation with dose recalculation workflow with Vision RT, shows greater robustness of D98% and maximum dose delivered to CTV, but minimum and average CTV doses are more robust with the ExacTrac workflow. Ultimately, the simple investigation does not identify a better workflow/device in an absolute way but indicates the need to carefully evaluate the choice to make according to the clinical requirements considered as priorities in different cases.

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Title:

A prospective clinical implementation of stereotactic radiosurgery for spine metastasis treatment: from algorithm configuration to Patient Quality Assurance

Prospective/Objective: The goal of radiosurgery is to deliver the prescription dose inside of the target and a steep dose drop-off outside the target volume. This work has been prepared to facilitate beam data acquisition for Eclipse beam configuration in SRS mode, highlight spine metastasis treatment process and from that, perform end-to-end testing using different test objects in an effort to validate the accuracy of TPS dose calculation.

Materials and methods. Firstly, measurements were done in MP3 water phantom using microLion chamber (0.002cm3) for PDD/Profile, semi-flex 0.125cm3 for output factors and MLC transmission/DLG. Second we reported the importance of beam commissioning data review, and end-to-end testing based upon single fraction 16 Gy of VMAT spine metastasis SRS for validation of dose calculation. In the third part, the important of carrying out quality assurance procedures using arccheck and EPID was reported. Gamma analysis was performed with 3% /3mm criteria. Finally optimal DLG was determined using Arccheck.

Results. For 6MV_SRS, the build-up depth was 15mm and the dose at reference depth 66.20% versus 15mm and 66.31% for standard 6MV. The mean value of penumbra was 2.23mm. Measured mean MLC transmission and dynamic leaf gap were 1.33% and 1.33 mm respectively. The mean ± std of CI, HI, $\eta\_(50\%)$, high / low dose target regions difference(%), D2cm, R50%, high dose spillage and delivery time values were 1.40±0.03, 1.20±0.01, 31.74±2.10, 1.20±1.50 / 2.34±1.25, 81.53±9.17, 4.10±0.40, 0.05±0.08, 14.51±3.07 respectively. More than 98±1.35 % and 84.28± 2.51 % of the points passed the gamma criterion for EPID and Arccheck respectively. With optimal DLG (1.8mm), the mean Gamma passing rate was 96.39%, with a range from 94.6% to 99.91% using Arccheck.

Conclusions. Although one can do a substantial part of the basic validation of beam configuration with a single shot beam, it found insufficient to assess the geometric precision of the dose-fall off during arc delivery in SRS mode. It is therefore highly recommended to invest final plan quality in a detector system that can provide 2D and 3D dose information as well. The EPID was found suitable for the validation of VMAT treatment plans in high dose delivery while Arccheck failed. Using Arccheck, accuracy of dose calculation will be obtained with determination of optimal DLG value that depends also on the complexity of the plan, target volume and the prescribed dose.

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