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Title:

Evaluation the Accuracy of Monte Carlo calculation Model Implemented in Monaco Treatment Planning System for Plastic Phantom Dosimetry in radiotherapy

Prospective/Objective: Test the accuracy and a consistent set of criteria for acceptability of photon beam dose calculations in plastic phantoms using Monte Carlo (MC) calculation algorithm model implemented in Monaco treatment planning system. Check the applicability in combination with a test used for evaluating the accuracy of the plastic phantoms dosimetry as a medium in radiation therapy

Materials and methods. Measurements are done by using plastic phantoms PMMA mass density 1.19 g/cm3and RW3 phantom mass density 1.045 g/cm3, irradiated open fields using a different source to surface distance (SSD) with different field size and different depths using Elekta Precise Linear Accelerator MLCi models with two photon energies 6MV and 15MV. The measured absorbed doses in the medium are compared with the calculated ones using MC calculation algorithm in Monaco TPS. Virtual electronic phantoms are simulated reproducing the same measurements setup. In this study we are comparing calculated absorbed dose with measured doses by using PTW 0.3 flex and pinpoint ionization chambers (ICs) with special insert slabs for both chambers. Measure of output factors on central axis at two different depths with RW3 phantom and one depth for PMMA phantom and for different fields size and SSDs are been performed for comparison with calculated data

Results. The accuracy agreement between calculated absorbed doses by Monaco TPS using MC algorithm and measured absorbed doses in RW3 and PMMA plastic phantoms instead of doses in chambers reading taking into account the correction and perturbation factors of corrected doses in plastic phantoms, for both energies and different setups of plastic phantoms; had acceptable accuracy and their confidence limits around 2%.

Conclusions. MC is the most accurate method of calculating dose distribution, has shown significant gains in accuracy of dose calculation in the plastic phantoms, the results of measurements done to check the accuracy of dose calculation in plastic phantoms by used MC algorithms. This results make us confident in using MC calculation plastic phantoms for comparison with pre treatment verification measurements as QA process in radiotherapy for IMRT and VMAT delivery.

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Title:

Small field dosimetry in clinical practice: estimation of micro ionization chamber

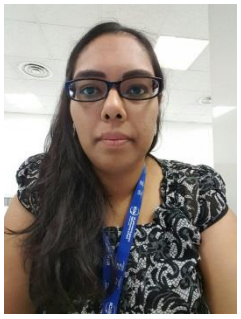
Prospective/Objective:
Stereotactic radiation treatments require small field delivery. The dosimetry of such fields is challenging, and a specific formalism was introduced in the last decade. The primary aim of this study was to determine the correction factors of 10 MV small square beam (or kfs) and small modulated beam or for Pinpoint PTW-31016 ionization chamber, using the Gafchromic EBT3 as reference detector. The secondary objective was to apply on stereotactic radiosurgery treatment(SRS).

Materials and methods. Two different sets of measurements were performed for the estimation of kfs and for the Pinpoint PTW-31016 ionization chamber, delivered on RW3 phantom at10 cm depth. The reference field for the correction factors estimation was 5x5cm2.Firstly,for kfs estimation a set of square beams was delivered to the detectors with different field size with 2Gy dose prescription at the isocenter. For correction factors four modulated beam with geometry similar to the SRS plan were produced with the Monaco treatment planning system(TPS)and delivered to the detectors in a sliding window technique. The calculated was then plotted as a function of beam segment area in order to find a fitting curve that can be used to correct ionization chamber measurements in pre-treatment verification of SRS plan. The estimation of, derived from that fitting, was verified with two clinical patient plans by comparing the corrected chamber measurement with the film measurement and with the calculated dose from the Monaco TPS.

Results. kfs increases as the field dimensions decrease: for 3x3cm2, 2.5x2.5cm2and 2x2cm2kfsis close to unity, as expected, while it is 1.027(±2.3%) for the 1.5x1.5cm2and 1.067(±2.9%) for the 1x1cm2. For the 0.5x0.5cm2field, kfs is estimated, from the fitting, to be 1.16(±1%).kpcsr increases as the segment area decreases and for the modulated beams considered the range of variation was between1.003 and 1.089.kfsestimated in this work are in good agreement with published data of kfsat 10MV: the differences areo.1% for 2x2 cm2, 1.5% for the 1x1 cm2 and 1% for the 0.5x0.5 cm2field. The kpcsr fitting curve showed an excellent agreement, with R2=0.999,and hence the fitting curve can be used to estimate the kpcsr of modulated beams used in SRS treatment. When we apply the on the two ion chamber values of the clinical plans, we find a good agreements with the film dosimetry: dose difference between chamber and film are

<0.5%.The ion chamber measurement after correction shows a better agreement with the TPS calculation(DVH mean dose to the chamber): dose discrepancy improved from 3.7% to 1.4%.

Conclusion. The good agreement with the published data of kfs allows us to use them to correct the Pinpoint PTW-31016chambermeasurements.
Kpcsr estimated from the fitting curve can be used to correct the ion chamber pre-treatment verification of the SRS coplanar beam; further work is required to extend these results for the verification of other kind of SRS treatment, especially when non-coplanar beams are used.



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Title:

PET/CT Acceptance Test and Optimisation

Prospective/Objective: To evaluate the performance characteristic of Philips Ingenuity TF PET/CT system (Philips Healthcare, Cleveland, OH, USA) of both PET and CT parts and to optimize the PET scanner and reconstruction protocols.

Materials and methods. Philips Ingenuity TF is a TOFPET/CT scanner equipped with LYSO type detector which generates images using list-mode reconstruction algorithm, and 64 slices CT with dose reduction tools such as DoseRight and IDose. In this work, the performance of the newly installed Philips PET/CT was evaluated for whole-body scanning procedure using National Electrical Manufacturers Association (NEMA) NU 2-2012 protocol and the recommended phantoms. The set of tests performed were spatial resolution, sensitivity, image quality, scatter fraction (SF) and counting rate performance, and accuracy: corrections for count losses and randoms. The test of the CT was performed by the Philips protocol and then using the CATPHAN the tests were repeated as per the hospital standard protocol for CT acceptance test. The impact on background variability, contrast recovery and relative error in lung by changing the reconstruction settings was analysed on the image acquired on IEC phantom with target to background ratio 4 and 8.76.For the optimisation process of the PET, 120patients'(males and females)data were analysed. The patients were injected with an activity ranging from 90 MBq to 200 MBq. The F18-FDG injection protocol of the hospital is 3 MBq/kg. Whole-body images corrected for attenuation were acquired with the LYSO PET camera60-70minutesafter tracer administration. The true count rates and random rates for each anatomical part (thorax and abdomen) were plotted against the activity injected to the patient. From the graph, the trend of the counts was observed for patients having BMI > 25kg/m2and those having BMI < 25kg/m2. The noise evaluation (Coefficient of Variation (CV) of signal on a ROI on the liver) was performed on the patients studied in this work, by changing the ESD from 60 seconds to 90 seconds per bed.

Results. The average transaxial and axial spatial resolution measured as full width at half maximum (FWHM) of the point spread function at 1 cm (and 10cm) off-axis was 4.68 mm (5.07 mm) and 4.71 mm (4,70 mm) respectively. The average sensitivity for the two radial positions (R = 0 cm and R = 10 cm) was 7944 (8415) cps/MBq. The average scatter fraction was 30.54%. The peak noise

equivalent count (NEC) rates was found to be 116.39 kcps at 19.21 kBq/ml (k = 1 in the NEC formula; noiseless random correction) and 93.79 kcps at 15.34 kBq/ml (k = 2; noisy random correction).By varying too much the reconstruction settings from the default setting shows that using the PSF shows a better contrast recovery compared to the default reconstruction settings. But using PSF with iteration number 2 showed an increase in contrast of above 100%.The optimisation process of the PET showed that there is no visible difference between the counts obtained by a patient with high BMI (>25) compared to a patient having a normal BMI (<25). The noise evaluation showed a significant difference in CV when the ESD was increase from 60 seconds per bed to 90 seconds per bed.

Conclusion. The results obtained for the Philips Ingenuity TF PET/CT scanner from the NEMA test are in agreement with the specification provided by the manufacturer. This PET scanner has an overall good performance which is comparable to other PET/CT systems from the same generation of TOF PET scanners. This work shows that the count rates of patients with low BMI (< 25 kg/m2) and high BMI (> 25 kg/m2) are superimposed, contrary to the situation of non-TOF PET scanners. This observation allows eventually to consider an increase in ESD, independently on BMI, but not to increase the administered activity. The PSF image reconstruction increases the contrast recovery and hence improves the image quality. Care should be taken while increasing the number of iterations beyond 1 as the contrast recovery will increase over 100% with an overestimation in the actual uptake of the lesion. Finally, the noise evaluation has shown that it is worth increasing the emission scan duration (ESD) to90 seconds with respect to 60 seconds per bed to decrease significantly the CV on the liver.

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Title:

Treatment planning for gynaecological cancer with 3D, simple IMRT and VMAT

Prospective/Objective: Radiation therapy treatment of gynecological cancer can be delivered with different techniques. In this study we compared the forward planned 4 field box approach with the inverse planned volumetric modulated arc therapy approach. The objective was to become familiar with different treatment planning systems, practicing in a clinical environment. This study could be helpful for my home country in the transition from the simple 4 field box technique that is nowadays used to a more advanced technique that will be introduced next year.

Materials and methods. Ten patients that underwent VMAT treatment for gynecological cancer were chosen; the CT dataset and the structures (target and organs at risk), were exported to a 3D CRT treatment planning system, and planned again with a four field box technique. Dose prescription was 45 Gy in 25 fractions, 15MV photon beams were used, the dose distribution within the PTV was optimized (95% of the prescription dose covering all the PTV, while keeping the hot spots at less than 110%). The Fiorino et al approach was adopted for the small bowel constraints (V30Gy, V40Gy and V45Gy tolerances are defined for IC07, i.e. the whole intestinal cavity minus PTV, with a 7 mm margin). VMAT plans were previously done with a full arc (360°) 10MV photon beam, optimized with inverse planning approach. The relevant data from the Dose Volume Histograms were tabulated for both techniques. The conformity index was calculated for each plan. A comparison between the two techniques was performed, using statistical analysis methods.

Results. The results were analyzed with R software, with non parametric data two tailed paired Wilcoxon signed rank test. The level of confidence was p-value <0.01 .For planning target volume, most of the plan shows a good coverage, homogenous dose distribution, maximum dose around 110% and minimum dose equal or more than 95% . Both techniques are statistically not different. Regarding IC07 there is a statistically significant difference between VMAT and 4 field for all the investigated parameters (V30Gy, V40Gy and V45Gy): VMAT shows a reduction in median values of 61%, 86% and 100% respectively. Regarding conformity index for IC07 there is a statistically significant difference between VMAT and 4 field, with a reduction in median values of 29%. Regarding the bladder mean dose there is a statistically significant difference between VMAT and 4 field, with

a reduction in median values of 6%.

Conclusion. The VMAT technique leads to a coverage of the PTV comparable to the one obtained with 4 field technique, while better sparing the intestinal cavity, due to the improved conformality of the high dose region. If it's not possible to have VMAT capability, a optimized 4 field box technique can be a good solution anyway, provided a stricter follow up is conducted, to help facing any clinical consequence due to the higher doses to the small bowel.

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Title:

Statistical process control analysis for patient-specific pre-treatment VMAT QA with PTW Octavius 4D system: setting tolerance limit and action thresholds for different anatomical sites

Prospective/Objective: Pre-treatment patients specific QA are used to validate the dosimetry of VMAT plans and to evaluate dosimetric performance over time of VMAT QA process. The aims of this work are: I)to determine specific Tolerance & Action Limits for VMAT QA of different anatomical sites II)to find a correlation between plan complexity metrics and 3D volumetric gamma passing rates for pre-treatment VMAT QA

Materials and methods. 464 VMAT QA performed in the Florence Radiotherapy Center of the Azienda USL Toscana Centro for patients treated in the period 2013-2018 were evaluated. All patient specific pre-treatment QA verifications were performed by the OCTAVIUS 4D phantom with OCTAVIUS 729 detector. Global and Local 3D volumetric Gamma evaluations with normalization at the 90 % of the maximum dose and different criteria (3%,3mm, 3%,2mm, 2% ,2mm) were performed. Six different anatomical sites were considered: Head and Neck, Lung, Breast, Prostate, Prostatectomy, Abdominal &Pelvic. Firstly, the analysis was based on the whole VMAT QA sample in order to evaluate retrospectively the behaviour of the process over a long time with a large number of pre-treatment QA. Secondly, the analysis was based on a small group of pre-treatment QA (last 20 pre-treatment QA performed for each anatomical sites), in order to monitor the process in a prospective approach and to track the variation of process based on the current status of QA results. In both analyses, the descriptive statistical parameters are calculated for each site of patient and Action &Tolerance limits were established by using the concept of Statistical Process Control, as suggested by AAPM Task Group 218.The Modulation degree, Total MU number and total Leaf Travel were calculated from the DICOM RT files of 120 VMAT treatment plans, 20 for each of the six involved anatomical sites. The relationship between plan complexity and the 3D volumetric global gamma index analysis with 3%, 3mm criteria was investigated. Pearson correlation analysis was performed and considered statistically significant for p-value < 0.001.

Results. Tolerance Limit for complete data set for Prostate, Prostatectomy, Head & neck, Lung, Breast, Abdominal sites were 98.6%, 97%, 91.3%, 91.2%, 91.2%, 88.4% respectively and action limit were 97.8%, 95.5%,

87.6%, 88.5%, 87%, 86%. Tolerance Limit and action limit evaluated on the small data set of QA results were higher than the previous ones for each anatomical site allowing a reduction in the variation of QA results. Average modulation degrees were ranging between 2.4 and 7.5 respectively with the lower modulation observed in prostate cases and higher modulation in Abdominal treatments. The average MU number was ranging between 524 for prostate treatments to 968 for breast plans. The average total leaf travel was minimum for prostate plans and maximum for abdominal plans. A significant negative correlation between each examined complexity parameter and 3D volumetric gamma passing rates was observed showing that for higher value of complexity metrics, lower pass-rates were scored. A Strong positive correlation between each other of the examined parameters (Modulation degree vs Total leaf travel, Total MU vs Modulation degree, Total MU vs Total leaf travel) was found too

Conclusion. Action thresholds for VMAT QA treatments stratified for different anatomical sites were established. These limits could be used to accept or reject patient treatment plans for the specific systems used in this work. The observed correlation between plan complexity metrics and 3D volumetric gamma passing rates showed that planning and QA verification procedures should be considered as a whole process. Some parameters, which have a significant impact on plan dosimetric accuracy, should be controlled during plan optimization, thus reducing the complexity of the plan.

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Title:

Commissioning of Total Body Irradiation for a new installation

Prospective/Objective: The project was aimed at commissioning of the Total Body Irradiation (TBI) technique in a new installation at Maggiore Hospital, Radiotherapy Department.

Materials and methods. Calibration of detectors, Gafchromic EBT3 (GAF), MOSFETs and Ionization chambers (CI), was done under reference conditions for use in TBI conditions. Three reference positions: Source Axis Distance (SAD) 5m (2m from the wall), SAD 4.5 m (2.5 m from wall) and SAD 4m (3 m from wall) were chosen with minimal or no backscatter from the wall. A treatment technique: Lateral-Lateral (LL), gantry angle 900, collimator angle 00 and 6MV energy was chosen with respect to the nature of the bunker. Percentage Depth Doses (PDDs) were evaluated, first with a big water phantom and then with RW3 slab phantom (30x30x30 cm3) at the three positions and then compared. The flatness and symmetry of the profiles were evaluated from the water PDD data. The beam quality was also determined using $TPR1020$ in TBI conditions. Then in vivo doses were measured with both GAF and CI using RW3 phantom by taking three points on the RW3 phantom: 5 cm from entrance (entrance dose), middle slab (midline dose) and 5 cm from the exit (exit dose). These were compared for GAF and CI. Additionally, previsional calculations for Monitor Units (MU) were made to achieve the nominal prescribed dose of 2Gy at the umbilicus, with 1Gy from either side of the patient. Lastly, the absorption of lead and plexiglass as shielding materials was measured and the corresponding absorption curves plotted.

Results. The beam was characterized in different setups. A length of 140 cm (pediatric) was found to be in the flatness region with a dose variation of 3% while 170 cm (adult) had a dose variation of 10%. $TPR1020$ was found to be 0.9888 at 2.5 m from the wall. The correction factor (for all influence quantities) changed from 0.994 in isocentric conditions to 0.991 in TBI conditions. GAF, MOSFETs were calibrated and a calibration curve was plotted for GAF while a table of calibration factors was made for the MOSFETs. A dose variation of less than 2% was achieved between Farmer chamber and GAF readings at similar points in the RW3 phantom.

Conclusion. The beam characteristics were important parameters to understand the behavior of the beam in non-reference conditions (TBI conditions). These were within tolerance range as dose variations

of up ±10% is allowed in TBI conditions. The doses measured with the CI and GAF were compared with less than 2% difference and this meant they can be used in any TBI setup. Therefore, the bunker was found fit for carrying out the TBI technique and the first patient who was irradiated after the commissioning was a very good experience.

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Title:

Characterization of diamond detector for dosimetry in the reference and non reference conditions in the flattening and flattening filter free beams

Prospective/Objective. The goals of this work are to characterize new Synthetic Single Crystal Diamond Detector (SCDD) for the dose measurements in the radiation therapy photon beams, in order to use safety it to check the accuracy of TPS modeling for the dose calculation in small field size, penumbra region and dose build up region, to investigate the optimum conditions in which SCDD operate in comparison with other detectors, to find out the possibility of using SCDD for calibration of Delta4, that is the instrument that we use for Delivery Quality Assurance (DQA), that use diodes as detectors.

Materials and methods. The dosimetric properties of a synthetic SCDD were assessed and compared with the FC65-G, A14SL and CC13 ionization chambers measurements of different parameters. The SCDD was operated at zero bias voltage under irradiation with different higher energy photon beams using different dose rates while other detectors were operating at +300V. In all measurements performed, the detectors were connected to the PTW Unidos Electrometer. In this work, True Beam Varian LINAC was used to provide all radiation X rays energies. The Wellhofer IBA Dosimetry Water Phantom (Blue Phantom) was used for acquiring data. Pre irradiation dose of 5Gy were performed before using the detector in order to stabilize the detector as recommended by manufacture. The first task was to perform the constancy check of SCDD and FC65-G using Sr-90 check source. The time between 50s and 400s with the interval of 50s was used, followed by the measurements of SCDD dose response linearity. The field size of 10cm x 10cm, SSD 100 and 10 cm depth were used. The two nominal energies 6MV and 10MV were selected with and without Flattening Filter. Furthermore, the dose rate dependency of SCDD and FC65-G was also determined and compared using 10 x 10 cm2 field size, 10 cm depth, 100cm SSD and 50 MU.

The energy dependency of SCDD and FC65-G in photon beams of nominal energy 6 MV Flattening Filter (FF), 6 MV Flattening Filter Free (FFF), 8 MVFF, 10 MVFF, 10 MVFFF and 18 MVFF beam qualities were measured and compared using the two measured dose in reference condition, with constant dose rate of 400 MU/min and 100 MU were used. The angular dependency of SCDD was assessed in radial and axial directions. In radial direction gantry was rotated from 0° to ± 40° with the detector inserted into the Phantom. In axial direction detector was free in air, inserted in the buildup cap with gantry

rotated from 00 to 180°. In both set up the field size of 5 x 5 cm2, 6 MVFF beam quality, 100 MU/min and interval of 10° gantry angles were employed. Beam profiles and Percent Depth Dose for 1x1, 2x2, 10x10 and 30x30 cm2 fields were acquired using SCDD for 6 MVFF and 6 MVFFF beams. Then measurements were compared with the ones measured with A14SL, CC13 and extracted from TPS. The Output Factors (O.F.) for rectangular fields were measured using SCDD and compared with the ones measured with A14SL, CC13 and extracted from TPS. Different rectangular field sizes were obtained by alternate fixing X and Y jaws. Finally, temperature dependency of SCDD was determined in the range between 20° to 30° C, with field size of 5 cm x 5 cm for 6 MVFF beam quality.

Results. The SCDD shows positive linear response with the dose measured with R2 = 1. Constancy checks also indicate positive linearity with R2 = 0.999 and with ±0.009 (k =1) STD. The response is independent from dose rate with values within ±1%. It was found that the SCDD dose measurements are in agreement with Farmer measurements within ±0.7 % at different beam qualities. The angular dependency of the SCDD was ±0.5% in radial direction and ≤ 0.9% gantry angles in axial direction. PDDs and Profiles for all energies, field sizes and depth acquired by SCDD were in good agreement with those measured with A14SL,CC13 and the ones extracted from TPS.

Conclusion. The results convinces that SCDD investigated is suitable for measurements in reference and non reference condition and small field dosimetry. It was found that TPS can provide correct dose calculation also for 1x1cm2. The diamond detector can be used to calibrate Delta4, as it has negligible angular, energy, dose and dose rate dependency.

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Title:

IMRT dosimetric commissioning of a Monte Carlo based TPS using the AAPM TG 119

Prospective/Objective: IMRT planning demands strict quality assurance and accurate dose determination for delivery of highly conformal dose to the patients. Some procedures from the AAPM Task Group 119 have been given in order to assess the planning and deliver systems. The aim of this survey was to verify whether the Monte Carlo algorithm on Monaco software could meet the plan goals suggested in the protocol and also to verify the accuracy of dose delivery mechanism in a linear accelerator. Thus, the comparison between calculated and measured dose distributions of some specific plans has been done to test the treatment planning system and then it has been assessed as recommended by the TG119 .

Materials and methods. This dosimetric verification has been achieved for photon beams of 6 and 10 MV. First, a measurement of simple open field plans with a water phantom and ionisation chambers placed at 10 cm depth was performed. The report of dose output, percentage depth dose and profiles scans have been made for this part. These acquisitions have allowed the creation of a new kernel to be installed in our TPS; this had to be tested. The planned dose of some of the measured beams at the beginning has been done with this TPS and compared with measured dose in order to verify the accuracy. Secondly, the comparison for complex geometry field, i.e. MLC-shaped plans, was done and the phantom Delta 4 has been used for the acquisition of the five beams for each energy. To finish the Task Group 119 recommendations have been followed to assure the suitable dosimetric commissioning of our TPS. The plans have been done on structure and computed tomography scanned data set downloaded from the AAPM website. IMRT test planning has been performed to achieve conformed dose and dose distribution similar to the one described in the AAPM TG119 report. All the beams of this work have been optimized and calculated with Monte Carlo based Elekta Monaco treatment planning software and the delivery system was Elekta Synergy S linear accelerator. The data analysis has been realized with the Beam Data Analysis Software for the first part and then the Delta 4 software has been used for the both others

Results. The open field planning had a dose calculation accuracy lower than 2% with 2% and 2 mm acceptance criteria. Complex fields planning had all pass rates higher than 99.6% for 3% and 3 mm criteria and 95.8% for 2% and 2 mm criteria. Concerning the five tests from TG119, the planned dose distributions have respected dose prescription recommended by the group mostly; the others were within mean ± SD results of AAPM TG119 facilities. The comparison between calculated and measured dose of these tests for 3% and 3mm and 2% and 2mm gamma criteria has given respectively a mean passing rate of 99.4% and 97.5% and a confidence limit of 2.5% and 7.6%. The results were in good agreement with the Task Group recommendation

Conclusion. The good results obtained between planned and measured dose distribution and their comparison with reference recommendations have allowed to assure the accuracy and validate the commissioning of the new treatment planning system and our delivery system.

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Title:

Commissioning of Varian Eclipse version 15.5 TPS for photons 6 MV and 6 MV FFF from Varian TrueBeam STx

Prospective/Objective: This work dealt with the measurements of basic dosimetric aspects of commissioning for conventional 6 MV (WFF, With Flattening Filter) and 6 MV Flattening Filter Free (FFF) photon beam from a LINAC Varian True Beam STx in the Eclipse 15.5 TPS (algorithm of dose: AAA).

Materials and methods. Measurements of basic beam data (PDD curves for a range of fields, beam profiles (OARs) at different depths, relative Output factors for various rectangular field sizes ranging from 2 × 2 cm2 to 40 × 40 cm2, Multi Leaves Collimator dosimetric parameters) for the modelling are done with Blue-Phantom2 water phantom (IBA dosimetry). The following detectors were employed: Semiflex 3D (PTW) (for measurements of PDD curves, relative output factors for small fields and absolute dosimetry), Microdiamond (PTW) (for measurements of beam profiles at different depths), CC13 chamber (IBA dosimetry) (for measurements of beam profiles of large fields and output factors larger than 4x4 cm2), IBA Farmer-like chambers FC-65p Wellhofer IC 69, FC-65G Wellhofer IC 70 (for reference dosimetry and MLC dosimetric parametrization). Since FFF beams are characterized by a value of dose per pulse greater than conventional beams, ion collection efficiency within the scanned volume was investigated to establish if it affects the shape of beam profiles. For the absolute dosimetry for 6 MV and 6 MV FFF beams, Code of Practice TRS398 and the recent Cop TRS 483 were adopted respectively basing on Famer-like chambers. Furthermore, for clinical reference dosimetry, 3D Semiflex chamber was used too. For driving the TPS commissioning and its analysis, different guidelines were studied. In particular, we paid attention to the recommendations by AAPM (MPPG 5a). To test the match measurements /calculated values, we applied an open-source software tool (MPPG #5 Profile Comparison Tool created in MATLAB environment as part of a multi-institution research collaboration) to compare scanning water tank measurements to 3D DICOM-RT Dose distributions. Implementation of tolerance values and evaluation criteria were discussed.

Results. 6MV-FFF has a softer spectrum compared the conventional beam, so their PDD curves are steeper. Relative Output factors for FFF beams show reduced field-size dependence, as a consequence of minor head scatter. The results of the validation tests of the model meet the tolerances for the basic beam data. Besides, the use of PCT for analyzing the basic tests

allowed us to detect characteristics of the model not explicitly evaluated in beam Configuration of Eclipse.

Conclusion. Basic Beam data showed good agreement with the calculated. PCT revealed a valid, simple, quite flexible framework for commissioning and validation of TPS dose calculation algorithms. Remaining steps of the current study are the analysis of the TPS performance in different conditions compared to implementation and end to end tests for IMRT and VMAT planning.

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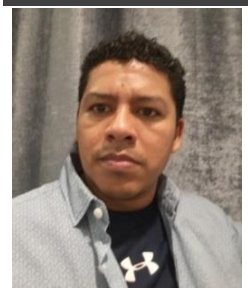
Title:

Applications of radiomic features to radiobiological models and radiomics: new strategies for selecting the optimal radiotherapy treatment plan

Prospective/Objective: The aim of this work is to select the most automated planning techniques to achieve a high probability of local tumor control (TCP) at a low risk of normal tissue complications (NTCP).

Materials and methods. 10 patients with prostate cancer, treated with a prescribed dose of 62Gy in 20 fractions were selected. Radiotherapy plans were made for every patient using 5 techniques (Box, Wedge, Field in Field (FiF), IMRT and VMAT) ranging from the less convenient, in terms of dose distribution, to the most modern and conformal (VMAT). The TPS chosen was Eclipse. The dose distribution obtained can be visualized as colour maps so radiomic features were extracted from them using 3D Slicer software. From the records of ten patients, the dose-volume histogram was used. Using radiobiological models the probabilities for tumor control (TCP) and normal tissue complications probability (NTCP) were calculated for each dose distribution to be used as gold standard for selecting the optimal plans and assessing a planning score between rival plans.

Results and conclusion. The features were correlated with the TCP and NTCP which are chosen as radiobiological variables using the package R as statistical tool. A Principal Component Analysis (PCA) is introduced for the analysis of the distribution of treatment plans. It identifies linearly independent combinations of parameters that summarize the statistical correlations present in the data. Radiomics has been used to identify more appropriate indicator able judging the more appropriate technique for the prostate cancer patients able to increase the TCP while sparing the organs at risk (bladder and rectum).



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Title:

Comparison of different simultaneous integrated boost (SIB) approaches in whole brain irradiation of metastatic disease with hippocampal sparing

Prospective/Objective: We want to investigate the main magnitudes involved in the treatment dose of HS-WBRT-SIB through the analysis of the main characteristics defined in ICRU report 83, so that we can evaluate the overdosage of WB considering the intermediate doses received by the patients. organs when the dose prescribed for WB and the metastatic lesion are between 30 and 40 Gy respectively.

Materials and methods. Ten cases of patients with cerebral metastases were treated with HS-WBRT at Azienda Ospedaliera Universita Integrata -Verona, Italy. These had been planned with the ECLIPSE software version13.6.23and treated with the Linear Accelerator DHS for VMAT and 2100 for IMRT of VARIAN, both with HDMLC Millennium120 collimation system and for Tomotherapy was used Tomotherapy planning station 5.1.12, when re-planning, CTs have been taken from already treated passages with fusion of magnetic resonance images and the process has been reedited from the contour of the structures, and the planning of the treatment. each pass was re-planned for the three techniques and with the data obtained from the planning system in the RT-Plan, the dose homogeneity index, the PTV coverage index, the behavior of the doses near to the minimum and near to the maximum were analyzed. as described by ICRU 83.In addition to the statistical analysis we will help the XLSTAT tool which allows us to perform the Freidman test to the data of interest

Results. PTV WB -IPPO -META is a volume that is totally covered when we analyze isodose of 98 and 95%, for the three techniques. For D98% we find: for IMRT 28.91Gy, for VMAT (28.83Gy) and for TOMO (29.09Gy). In relation to the dose close to the maximum, the results obtained were: for IMRT (34.22Gy), for VMAT (32.87Gy), and for TOMO (31.97Gy).The indices of conformity found through the analysis of the data are: in the 95% isodose: IMRT (1.23), VMAT (1.22), TOMO (1.26).in the isodose 98%: IMRT (0.94), VMAT (1.05), TOMO (1.12).As for the risk organs, all comply with the internal restrictions of the hospital.

Conclusion. In the evaluation of the three treatment techniques (IMRT, VMAT and TOMO) through of the analysis of dose-volume histograms (DVH) We found that the coverage of the defined white PTV and defined risk organs are respected in the different plans. Regarding the dosimetric result no significant

variance was found between the three techniques analyzed with respect to the modal dose, if between doses near to the minimum D98% and near to the maximum D2%, where the significant differences are between volume and IMRT. The percentage of underdosing of the PTV WB for the dose near to the minimum D98% is: 3.64% for IMRT, 3.9% for VMAT, 3.04% for tomotherapy, As for doses near to maximum D2%were obtained overdosage percentages of: 14.05 % for IMRT, 9.56% for VMAT and 6.57% for Tomotherapy. According to the analysis performed with the statistical software we conclude that the best results for the treatment of HS-WBRT-SIB are obtained with the treatment of tomotherapy but if this is not available VMAT is a possible option.

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Title:

Assessment of the spatial, temporal and dosimetric accuracy of a linear accelerator dedicated to stereotactic body radiation therapy (SBRT)"

Prospective/Objective: The scope of this work was to commission Varian TrueBeam STx linear accelerator equipped with BrainLab ExacTrac in-room X-Ray based monitoring system, Vision RT AlignRT optical solution for IGRT, Varian RPM system for motion management and to assess the spatial, temporal and dosimetric accuracy for SBRT implementation.

Materials and methods. Varian TrueBeam STx linear accelerator equipped with BrainLab ExacTrac in-room X-Ray based monitoring system, Vision RT AlignRT optical solution for IGRT, Varian RPM system for motion management was commissioned. Measurements required by vendor to model the beams in the treatment planning system were performed: percentage depth doses, profiles both transversal and longitudinal, output factors, MLC transmission factors and dosimetric leaf gap. Measurements for EPID dosimetry were carried out. Commissioned energies were 4 MV, 6 MV, 8 MV, 10 MV of photons with flattening filters. 6 MV FFF and 10 MV FFF photon beams were commissioned as well. Dosimetric characteristics of beams with flattening filters were compared with flattening filter free beams. For electron beams energies of 6, 9, 12, 16, 20, 22 MeV were commissioned. The data was processed and input in the Eclipse treatment planning system. Measurements of small fields were performed with a MicroDiamond detector, and they were compared to measurements with a 0.125 cc ionization chamber. Several tests were performed in order to assess the spatial, temporal and dosimetric accuracy. The results were compared with recommended tolerances for SBRT treatment.

Results. Commissioning of Varian TrueBeam STx Linear Accelerator was successfully carried out. Softening of beam spectra and loss of beam hardening effect yield reduction in PDD at 10 cm for 6 MVFFF and 10 MVFFF beam from their corresponding 6 MV and 10 MV FF beam were 4.6% and 3.6% observed respectively. Flatness and symmetry of scanned profiles of 4, 6, 8, 10 MV flattened beams were not exceeding 2% and 1% respectively. Evaluated data, such as PDD, TPR etc., was fully compliant with the published literature. After the data was inserted into the TPS, a model beam was calculated for 6 MV and then compared with measured data. The biggest difference was observed in PDD curves, more precisely in the build-up region the difference was up to 5%. This data helps

to understand the limitation of TPS used for dose calculation, and avoid errors. With AlignRT real time monitoring on test object was performed with moving couch 1 cm and 5 degree in each axis of motion. Tracking was confirmed to be within <0.5 mm and 0.5 degree of accuracy. More precisely: vertically 0.1 mm, longitudinally 0.2 mm, laterally 0.1 mm and 0.1° rotationally. Accuracy validation test showed RMS of 0.113 mm, 0.385 mm, 0.170mm, 0.075° for vertical, longitudinal, lateral and rotational errors respectively.

Conclusion. The results obtained during this work are within the tolerances for SRS/SBRT techniques, hence the system assessed in this work is adequately suitable for SBRT treatment.

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Title:

Comparison of advanced techniques for radiation treatment of prostate, breast and Oropharynx malignancies

Prospective/Objective: To compare the dosimetric performance of advanced radiotherapy techniques used for radiotherapy treatment of prostate ,breast and Oropharynx malignancies; evaluate variation of TPSs parameters, optimization functions, calculation grid resolution, and assess of the impact of the number of segments, beam configurations and planning solution allowed by different LINAC and TPSs.

Materials and methods.: A total of 83 plans were optimized for 25 patients (eight prostate, eight breast and nine oropharynx cases). For prostate and breast cases 3DCRT, IMRT and VMAT plans were generated. IMRT plans of prostate cases were prepared in three versions, investigating impact of the number of segments and calculation grid resolution during the optimization process. Cases were studied using dose grid of 2 mm and 4 mm varying the optimization segments between 40-70 segments in order to optimize time of delivering. While VMAT plans of breast cases were optimized using single and dual arc mode, respectively to evaluate an optimize coverage of the PTV and sparing of the OARs. For Oropharynx cases, IMRT and VMAT plan where assumed as a standard techniques and none 3DCRT was investigated for these cases. The plan and analysis is performed for two different TPS (Pinnacle v.9.8 and Raystation v.8a) assuming delivering of the plan with two LINACs Elekta (Synergy and VERSA HD).To minimize time, and automatize extrapolation of dosimetric data an in-house code was developed using Octave to optimize DVH data and dosimetrical analysis, to calculate and compare index and metric calculation. A complex statistical analysis was performed using ANOVA and Tukey's HSD statistical tests and provide automatic generation of the box plots graph.

Results. Results showed no significant difference between different versions of IMRT and VMAT plans. Concerning prostate cases all techniques satisfied limits of PTV coverage as suggested by ICRU 83. VMAT and IMRT showed significantly less values for the range V_{40}-V_{70} of rectum and V_{75} of bladder comparing with 3DCRT ($p<0.01$). VMAT achieved higher dose sparing in interval V_{40}-V_{60} of rectum comparing with IMRT ($p<0.03$). Concerning breast cases, VMAT achieved significantly higher values for D_{98}, D_{95}, D_5 and D_2 of PTV comparing with IMRT and 3DCRT ($p<0.005$). 3DCRT had the highest homogeneity ($p<0.0005$) and the least V_{20} of contralateral lung and D_2, V_{20} and V_{30} of heart of left breast cases ($p<0.017$). While VMAT achieved significantly lower Dmean of heart of left breast cases and higher

Dmax of contralateral breast ($p<0.01$) comparing with 3DCRT and IMRT. Concerning Oropharynx cases no significant difference between techniques was found in terms of PTV metrics. VMAT achieved significantly less values for V_{40} of ipsilateral parotid and less values for Dmean of ipsilateral parotid and Dmax of spine comparing with IMRT (with $p<0.04$, $p<0.01$ respectively). Both the techniques had succeed (in average) the dose constrain of ipsilateral parotids due to the relative position within PTV.

Conclusion. For prostate cases VMAT was superior to IMRT in terms of PTV and OARs metrics. This is extendable to breast cases with performance of IMRT similar to that of 3DCRT. While for cases of Oropharynx VMAT and IMRT showed equivalent performance, but the delivery time is significantly decreased using VMAT, as reported in literature and this can contribute to optimize patients access to the clinical service. The developed code shown to be usable, fast and applicable to similar studies. These results can be useful for management evaluation in investments and clinical assessment of patients cohort and also in randomized controlled trials.

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Title:

A Comparative Analysis for quality assurance result of IMRT and VMAT Cancer Treatment Plans using three dosimetric tools

Prospective/Objective: Patient-specific quality assurance (QA) for intensity-modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) is extremely important in ensuring quality care for cancer patients in radiation therapy. The main objectives of this study is to analyze the sensitivity of different types of detectors by comparing their gamma index passing rates and investigate the sensitivity of various gamma criteria in intensity modulated radiation therapy (IMRT) and Volumetric modulated arc therapy (VMAT) quality assurance (QA) for the detection of systematic positioning and dose errors using an electronic portal imaging device (EPID), cylindrical (ArcCHECK) diode arrays.

Materials and methods. Various methods, including the use of an ion chamber, two-dimensional (2D) array detectors, and an electronic portal imaging device (EPID), have been employed during patient-specific QA in pre-treatment verification to detect possible errors between the dose calculated by the treatment planning system (TPS) and the measured dose. Due to the increasing complexity of modulated treatment plans and delivery, point dose measurements using an ion chamber alone may not be sufficient to verify dosimetric accuracy because a modulated plan can generate a steep dose slope near the organs at risk. A common tool for evaluating the agreement between the calculated dose and the measured dose is the quantitative comparison of the planar dose distribution using the gamma index.

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Title:

Comparison of beam characteristics in reference and non reference conditions and treatment plans for flattening filter and flattening filter free photon beams

Prospective/Objective: The objective of this thesis is to evaluate dosimetric difference between flattening filter free and flattened photon beams of Varian True Beam TM linear accelerator and to investigate the difference in treatment plan quality of different treatment techniques for selected brain cancer with flattening filter beam and flattening filter free beam.

Materials and methods. Non reference condition dosimetry were performed with IBA water phantom dosimeter system (RFA-Blue Phantom) with Omni-Pro Accept-7 software. AAPM TG-51 and IAEA TRS-398 protocol were used for dosimetry in reference condition for both flattening and flattening filter free photon beams. Comparison was made between the two protocols for the two beams. The procedure for Dosimetric Leaf Gap and MLC transmission factor measurements were carried out according to Varian specified guidelines. The chamber used for beam data collection and measurements were CC13, A14SL, A1SL, PTW30012 and FC56-G.

For treatment plan comparison fourteen patients with brain cancer were studied. A total of twenty eight treatment plans were generated using flattening filter beams and flattening filter free beams among which 10SRS, 6SRT, 6VMAT and 6IMRT plans. Standard clinical constrains were provided by the physician for planning target volume (PTV) and OARs. These were applied to generate the treatment plans. All plans were optimized and calculated using AAA algorithm of Eclipse treatment planning system. All treatment parameters such as iso-center position and beam set up were set to be identical for the flattened and the FFF beam plans. The homogeneity index (HI), gradient index (GI), target coverage (TC) and conformity number (CN) extracted from Dose-volume curves were used to compare the plan quality. The monitor unit number and beam on time were used to evaluate the delivery efficiency of treatment plans.

Result. Compared with FF beams, Dmax was shallower for FFF beams for all field sizes; the ionization curve shows smaller gradient for FFF beams in build up region. The FFF beams depth-dose curve shows a faster dose falloff compared with FF beams. As compared to FF beams, the output factor for FFF beams shows less variation with field sizes. FFF beams had lower MLC transmission and Dosimetric leaf separation than the FF beams.

In all four techniques the FFF beams provides the same TC as

the FF beams. However, the use of 6MV FFF beams offers a clear benefit in delivery time when compared to 6MV FF beams, especially for SRS treatment techniques. It was obtained that compared to 6MV FF beam 6MV FFF spared 54.4%, 12.9%, 24.3% and 32.16 % of Beam On Time (BOT) in SRS, VMAT, SRT and IMRT techniques respectively. With regard to MU no significance difference were observed for VMAT and SRS techniques, but clear difference in MU were obtained in SRT and IMRT techniques: 6MV FFF uses higher MU amount than 6MV FF to achieve the same TC. The highest difference was obtained in IMRT in which 6MV FFF uses MU 1.5 times those of 6MV FF. From DVH analysis of OARs, FFF plans obtained better normal tissue sparing effect than FF plans in all four techniques.

Conclusion As expected, removal of flattening filter alters various commissioning associated parameter such as beam quality, MLC Leaves Transmission factor and Dosimetric leaf separation. It was observed that IAEA-TRS398 and AAP-TG51 protocols give comparable results for both flattened and flattening filter free photon beams for dosimetry in reference condition. Negligible difference in beam quality conversion factor was observed using the two protocols for both FFF and FF beams. Similarly negligible difference in ion recombination of available chambers was obtained using the two protocols. However, relatively higher recombination correction factor was observed for FFF beams as compared to FF beams with the same nominal energies for both protocols. The FFF has the benefit of faster treatment delivery with smaller dose to normal tissues. Those features will help to increase patient safety, increase patient comfort and reduce chance of developing secondary cancers after radiotherapy. In this study, we observed that, compared to 6MV FF beams, 6MV FFF beams obtained clear time sparing effect in IMRT and SRS techniques. However, in IMRT relatively higher MUs were used by 6MV FFF as compared to 6MV FF to obtain the same TC. Anyway, in compromise with its highest time sparing effect and insignificant difference in MUs between FFF and FF beams, for SRS techniques (in which high dose per session, from 7 up to 21 Gy, with different number of sessions) we can conclude that 6MV FFF beams is a good choice for brain treatment with SRS techniques.

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Title:
Evaluation of shielding for a facility where Volumetric Modulated Arc Therapy (VMAT) technique is to be used

Prospective/Objective: The purpose of this work is to assess the feasibility of reducing the bunker thickness when VMAT is to be used. The formalism of NCRP report 151 and treatment planning are applied so that we can estimate important parameters affecting shielding calculation such as use factor, modulation factor and field dimension. Measurements in the bunker for treatment plans delivered in 3D CRT, IMRT and VMAT were performed for the study.

Materials and methods. First and foremost, evaluation of the bunker shielding was performed using NCRP 151 formalism. In the second part, calculations of the use factor (U) were carried out for 30 radiation treatment planning (10 patients, each in 3D CRT, IMRT and VMAT techniques, therefore 30 plans delivered). Through Eclipse treatment planning system, the beam data was obtained from extracted RT images, exported to excel spreadsheets and data analysis performed in Matlab. Diagrams in rose plot of beam fields direction for each patient and each radiation treatment technique, graphs related to the workload in Monitor Units (MU) and in cGy were generated. Thirdly, the radiation treatments plans are delivered with TrueBeam LINAC. In this study, we compared VMAT treatments to IMRT treatments to estimating important parameters affecting shielding calculation such as the use factor, the modulation factor and field dimensions. Subsequently, we placed in the bunker the ambient dosimeters (TLDs) in different positions according to the shielding calculation on existing treatment room and established the correlation between modulation factor, treatment techniques and radiation shielding.

Results. Evaluation of the radiation shielding workload of the TrueBeam LINAC, using NCRP151 formalism is performed. The thicknesses calculated are then compared to existing ones. On the other side of the radiation treatment planning, the results were based on the workload for 30 radiation treatment plans in each treatment technique such 3D CRT, IMRT and VMAT used. After extracting data from DICOM-RT (RT plans) on the treatment plans including gantry direction (U) to deliver, the MATLAB tools was used and the resulting rose plot shows that the weekly workload in MU is less in VMAT than in IMRT. In VMAT, the workload in cGy is obtained by multiplying the effective fluence with the dose deposition matrix at each arc sector during the continuous gantry rotation. The modulation factor (MF) for each treatment technique was computed (1.8 for VMAT and 2.13 for IMRT). The dose in primary barrier is higher for IMRT than VMAT and the correlation established was approximatively equal to unity in respect to the secondary barriers and higher dose

for IMRT for primary and secondary shielding.

Conclusion. VMAT technique has the advantage to reduce significantly the number of MU, the treatment time, VMAT treatment plans generally use less MU compared to IMRT and which result in decreased whole body scatter dose, allow for more patient throughput and require short times. The shielding can be therefore reduced if the radiotherapy facility is dedicated to VMAT since there is a very strong correlation between treatment techniques.

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