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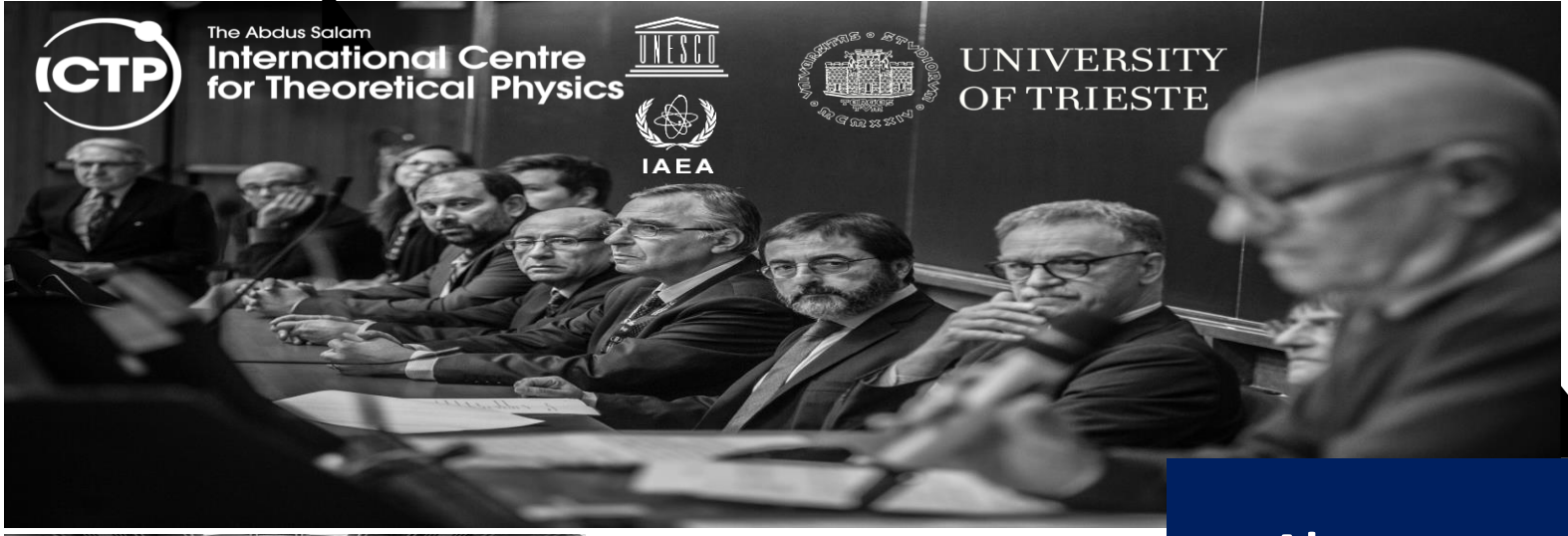

Abstracts Booklet of the MMP Thesis (8th & 9th cycles)

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Small field Dosimetry with the new generation Exradin W2 scintillator detector

Prospective/Objective: The aim of this study is to evaluate the new generation of scintillator detector, Exradin W2, for commissioning measurements and routine check in small field dosimetry.

Materials and methods: Percentage dose depth, transverse profile and field output factors were measured in a 6 MV beams for small field sizes ranging between 1x1 cm2 and 5x5 cm2 in a PTW MP3 water phantom with four different detectors: PTW 31016 PinPoint3D, PTW 60023 microSilicon, PTW 60019 microDiamond and Exradin W2 scintillator detector. The parameters analyzed for PDD curves were relative surface dose (DS), depth of dose maximum (Dmax) and of 50% of dose (R50) and percentage dose at 100 mm (D100). In addition, maximum difference in distance (mm) and difference in Percentage Dose (%), within the 20-80% PDD region for all detectors (PinPoint, microSilicon, microDiamond), with respect to the Exradin W2 were evaluated. Penumbra width and field size were derived from transverse profiles both in cross and in-plane profile for each field size with all four detectors and were compared. OFs measurements were performed for each field size by the four detectors at 10-cm depth, 100-cm source–detector distance. The 5 × 5 cm2 field size was used for the normalization of OFs. By adopting the methodology recommended in TRS4831 for small photon beam dosimetry, two orthogonal profiles were subsequently acquired with the smallest field size and each detector was positioned at the maximum detector signal point. The ratio of the readings in the clinical field and in the reference, field was evaluated for each detector. Then, the field output factor, was evaluated by applying the output correction factor for each detector and each effective field size. For the Exradin W2 no correction factors were applied. Relative Deviations between corrected measurements performed by each detector and the Exradin W2 were calculated.

Results: For PDD measurements, an agreement within ±2% was observed among the detector responses for all the field sizes over the whole PDD curve, except for the build up region. Penumbra width derived from in-plane and cross- plane profiles with the four detectors were within 1.5 mm for all field sizes. Field size differences evaluated for the four dosimeters were less than 1mm. For Field Output factors, differences between Exradin W2 and other detectors were less than 0.5% for field sizes larger than 1x1 cm2. For 1x1 cm2 field sizes we found a maximum difference of 2.9% between Exradin W2 and corrected PinPoint Ionization Chamber measurement. The combined uncertainties for the measurements were estimated to be within 1.5% for the all the dosimeters.

Conclusion: The new W2 Exradin detector proved to be a suitable detector for accelerator linear commissioning measurements and routine check in small field dosimetry. The problem related to the first commercial version of this kind of detectors, the Exradin W1, regarding the lack of possibility to perform scanning data measurements has been successfully overcome. The new electrometer MAX SD allows manipulation of baseline values like Cerenkov light ratio and collection of point measurements. In addition, the MAX SD can convert the Cerenkov corrected signal into analog output that can be read by an external single channel electrometer thereby making the W2 detectors useful for scanning dosimetry.

Novel Techniques of In Vivo Dosimetry in Low kV Intraoperative Radiotherapy

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Prospective/Objective: Intraoperative Radio Therapy (IORT) is one of the most attractive radiotherapy techniques now-a-days with several positive sides. During IORT, a very important aspect is in vivo dosimetry. The purpose of this study was to calibrate two types of dosimeters, radiochromic films (RC) and MOSFETs, for in vivo measurements in IORT with low-kV x-rays delivered by Intrabeam system for breast cancer patients. We also wanted to make a comparison of the characteristics between both dosimeters and at the end choose the most suitable one to be used in our centre.

Materials and methods: The Intrabeam system is a miniature kV x-ray source manufactured by Zeiss and is designed especially for IORT applications. The calibration of both EBT-3 RC films and MOSFETs were done with Intrabeam which is the 50 kV source. EBT-3 films were calibrated using the red and green channels of the absorption spectrum in the 0–15 Gy dose range delivered by the low kV source. We also checked the effect of different self development time and orientation of scanning of EBT-3 films. The calibration of MOSFET was done for the same dose values. We used the calibrated films for in-vivo dosimetry during IORT of breasts for doing an independent QC of the treatment by placing one piece of RC film wrapped in sterile envelope on the skin of the patient after breast conserving surgery.

Results: We found from EBT-3 calibration that, in the low dose range the red channel shows better sensitivity, while starting from 5 Gy the green channel has better sensitivity. Then we built the calibration curve of RC film for both channels & these curves were used to measure skin dose during IORT. Moreover, dose to an implantable cardiac device was measured using films. Results from MOSFET calibration showed linear response in the dose range of interest. Results from in vivo measurements performed with RC films showed that, the technique is completely safe from side effects to the skin. The value of skin dose to each of the patient was within the threshold which is 5 Gy.

Conclusion: We were able to complete the task with clinical evidence which showed an excellent result for the RC films. In conclusion we can say that, IVD with EBT-3 films is a feasible procedure. Measured dose to the skin indicates that the technique is safe from side effects to the skin. As we calibrated MOSFETs also, we found that, MOSFET is also a strong dosimetry tool which can be used for IVD to the OAR such as skin.

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Geometric and Dosimetric Validation of An Artificial Intelligence Based Auto-Contouring System for Radiation Therapy Treatment Planning: A Clinical Feasibility Study.

Prospective/Objective: Geometric metrics are often used to evaluate automated contouring methods. A dosimetric parameter analysis may be more useful in clinical practice, although it is frequently absent in the literature. The purpose of this study was to look into the effect of state-of-the-art AI-generated anatomical delineations on dose optimization in radiation therapy (RT) for patients with prostate, breast, and H&N cancer.

Materials and methods: The auto-contouring system was evaluated using a database of 60 computed tomography images comprising prostate, breast, and H&N structures. Clinically accepted reference plans are directly copied for dose calculation of auto contoured structure sets. Dice similarity coefficient (DSC), Hausdorff distance (HD) and Relative Volume Difference (RVD) were used to assess geometric performance of contours. Dmax, Dmean, and D0.03cc indices were used to analyze OAR dose distributions with manual segmentation as a reference. For measuring overall plan acceptability, normalized plan quality metrics were evaluated. A Wilcoxon rank sum test was computed between dosimetric metrics. Inter-observer variability was also assessed for prostate cancer site.

Results: AI-based segmentation saved more than 57% contouring time and achieved an average DSC of 0.80 for prostate, 0.90 for breast and 0.75 for H&N with a few exceptions and the average HD (& RVD) were below 13mm (0.20), 25 mm (0.22) and 11mm (0.25), respectively. The dose parameters, Dmax, Dmean and D0.03cc for the prostate, breast and H&N patients, showed agreement between dose distributions within ±8%, ±5% and ±3%, respectively. In all situations, the difference in plan quality was less than 8%. The dose parameters changed slightly due to inter-observer variability. The comparison between geometric and dosimetric metrics showed no strong statistically significant correlation without a few exceptions.

Conclusion: Although auto-contouring system achieved state-of-the-art geometrical performance, human review is still unavoidable. Plans, based on auto-contouring, do not overdose nearby OARs. The auto-contouring system is recommended as a standard starting point with institutional geometric and dosimetric validation.

Characterization of a solid-state detector gamma camera dedicated to nuclear cardiology

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Prospective/Objective: This study aims to characterize the solid-state detectors gamma camera DSPECT (Spectrum Dynamics Medical, Caesarea, Israel) by analyzing the quality of myocardial SPECT images through different figures of merit (spatial resolution, uniformity of perfusion, and contrast) over a wide range of counts statistics (1, 0.8, 0.6, 0.4, and 0.25 million counts) in the Left Ventricle (LV) wall while using an anthropomorphic phantom mimicking normal and pathologic LV perfusion conditions.

Materials and methods: The experimental part of the study was done in two sessions. Both sessions used an anthropomorphic phantom of the chest (Torso phantomTM and Cardiac InsertTM, Data Spectrum Corporation, Hillsborough, NC, USA) with lungs, liver, and dorsal spine insert included. Lung's insert is filled with Styrofoam beads and non-radioactive water to mimic the density of lung tissue attenuation. The first session consisted of the preparation of the anthropomorphic phantom by inserting a cold defect in the left ventricle (LV) wall simulating a transmural defect (TD) and the second one by mimicking a normal LV, i.e., without any cold insert. For the two preparations, the acquisition was made at different count statistics in the LV wall image area (1,0.8,0.6,0.4,0.25 million counts). Pathological phantom acquisitions were made twice for each count statistic and for each position (Ant, Lat, Post, and Sept) of the cold defect. The normal phantom was re-positioned three times and for each position, two acquisitions were performed for each level of count statistics. The quality of the reconstructed images was evaluated in terms of contrast of the internal cavity (C_IC), the thickness of the LV wall, and the sharpness index (SI). On the polar maps reconstructed from the short axis slices of the LV phantom, other parameters have been evaluated, including uniformity of segmental uptake for the uniform phantom and TD contrast and variation in the segmental uptake for the pathologic phantom.

Results: All the Images quality parameters (Thickness of the LV wall, Sharpness index, Contrast of the internal cavity, Uniformity of segmental uptake, contrast of the TD, and variation of the segmental uptake) showed no difference when moving from the reference level counts statistics (1 Mc) down to 0.25 Mc in the Left Ventricle wall. The segmental uptake of the uniform phantom showed a decrease in the perfusion in correspondence with the mid-basal infero-septal position, as already evidenced by the literature. Moreover, the TD contrast was significantly lower for the defect placed in the posterior wall, with respect to the other positions.

Conclusion: Our results demonstrate that in clinical circumstances and using the reconstruction parameters currently advised for the clinical routine there are no differences in the considered parameters along the range of counts statistics explored. This result allows to administer a lower activity to the patient or use reduced scan time, to enhance patient comfort and limit the radiation exposure of both patients and operators.

Partial Volume Effect (PVE) correction in Single Photon Emission Computed Tomography (SPECT) imaging

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Prospective/Objective: The purpose of this work was to implement a home-made post-reconstruction algorithm to correct the PVE in the SPECT image to improve its quality for better quantification in diagnosis and therapy

Materials and methods: The NEMA IEC phantom inserts the six spheres of different sizes to study the PVE of two activity concentration measurements of 4.6 and 12.19 mCi/L of 99mTc respectively filled with a 10:1 signal-to- background ratio. The scan was performed on the Discovery NMCT 670 GE using clinical protocol. The images were reconstructed by OSEM 2 iterations, 10 subsets, Butterworth filter 0.48, CT based attenuation and scatter correction was used. In addition, the non-filter image was studied. The system PSF was performed with the same protocol. Two methods were used to correct PVE. First, the post-reconstruction algorithm based on the mathematical theory implemented in MATLAB, was used to correct the PVE in SPECT images studied and the second method is the recovery coefficient (RC). The raw and corrected image quality of the IEC phantom has been studied in terms of RC and contrast. In clinical application, 10 Hepatocarcinoma patients treated with Yttrium 90 were studied. All data has been analyzed with MATLAB, image J, LIFE x v7.3.0 and Xeleris software.

Results: Results showed that at 4.6 mCi/L, a ratio of 10.26 was obtained for the filtered image only for the large sphere, while all other spheres, except the smallest of the non-filtered corrected image, achieved a ratio greater than 10. The mean recovery values measured at 12.19 mCi/L for the small spheres in the filtered image, were 38.18 % versus 0.8 % for the post-reconstruction method and the classical RC method respectively. PVE recovery in small spheres is more accurate for post reconstruction method. The mean recovery values for all spheres size, obtained by the post-reconstruction method for the filtered image were 45.16 % versus 47.45 % measured at 4.6 and 12.19 mCi/L respectively and for the non-filtered image 42.53 % versus 47.3 % measured at 4.6 and 12.19 mCi/L respectively. For the classical RC method, both image types gave 12.88 % versus 10.13 % measured at 4.6 and 12.19 mCi/L respectively. The quality of the image studied in terms of contrast showed that it increases as the size of the sphere increases. Clinical images of HCC patients treated with 90Y microspheres were corrected for PVE. A significative improvement in contrast was demonstrated after this correction.

Conclusion: The post reconstruction method has proven more effective for clinical use. It is based on the mathematical theory of deconvolution to correct the PVE and depends on the sigma PSF system for its configuration. This is not an ideal tool as it is also limited by the scanning procedure such as phantom filling or patient injection and system spatial resolution.

aCommissioning and clinical implementation of the 1600 SRS Octavius detector

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Prospective/Objective: To commission a new device for pre-treatment patient specific verification of stereotactic treatments plans, which is capable of reconstructing 3D dose with high resolution (Octavius 1600SRS)

Materials and methods: Octavius 4D system (PTW) consists of an ion chamber array embedded in a cylindrical phantom which, assisted by an inclinometer, rotates synchronously with the gantry. It measures planar dose distributions as a function of gantry angle in order to compute the resulting 3D dose distribution. There are diverse options for the ion chamber array, we used the new Octavius 1600 SRS (small field size, high resolution). We have used one TrueBeam linac STx with MLC HD 120, the TPS has been Eclipse (v.15.5) and analysis have been performed with Verisoft (v.8.1). The commissioning measurements consisted of the following tests: (1) matrix calibration factors variation with dose rate and field size; (2) Dose rate dependence; (3) Field size dependence; (4) influence of geometry on PSQA results; (5) verification and analysis of typical SRS and SBRT plans, comparing TPS-calculated versus measured dose.

Results: We found the following results for Octavius 1600 SRS): (1) The matrix calibration factors has shown a maximal variations of 2.80% and 4.10%, respectively for 6FFF and 10FFF beams, within the range of filed sizes and dose rates considered. (2) For dose rate dependence a maximal variations of 1.702% and 1.853% was recorded for 6FFF and 10FFF beams. (3) For what concern field size dependence a maximal variations, obtained at the smallest field of 1.498 % and 3.355% for 6FFF and 10 FFF beams was recorded with an energy dependence of 1.857%. (4) It has been shown that dose agreements can deteriorates when the main lesion is shifted from the center of the phantom and when PSQA are delivered in non-isocentric conditions. (5) Verification of SRS and SBRT plans showed that the 2%, 2 mm, cut-off 10% and mean local dose difference criterion could help to replicate the former PSQA outcome.

Conclusion: Octavius 4D system together with Octavius 1600 SRS is an adequate tool for patient specific QA of treatments requiring high spatial resolution, but the dependence of its response with field size and dose rate can hinder its clinical adoption if not properly tamed. The collected set of measurements suggests that PSQA results obtained with Octavius can approach those performed with IC or ArcCHECK if the following criteria are used for the analysis: -local 2%/2mm gamma with a cut-off of 10% of the dose and an action level of 95%; mean local dose difference with dose cut-off at 70% (to check the high dose regions) with an action level of 4%.

3D printed lung phantom design and applications in evaluating lung SBRT respiratory gating treatments with surface guided radiotherapy for positioning

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Prospective/Objective: This study aims to develop a 3D printed lung phantom as an add-on to the QUASAR™ respiratory motion phantom and use it to evaluate lung SBRT respiratory gating treatments and testing surface guided radiotherapy for positioning. In particular TPS dose calculation accuracy on two different scans was tested against Gafchromic film measurement on a gated treatment.

Materials and methods: We evaluated the median diameter and volume of PTVs (spherical equivalent) for lung-SBRT using Eclipse (Varian Medical Systems) version 15.5 treatment planning system (TPS), taken from 41 patients who underwent lung SBRT with free breathing and 36 patients who underwent DIBH treatment. In total, 42 Lung SBRT PTVs have been selected based on 3-8 fractions of the lung SBRT treatment since 2021. The average planning volume (PTV diameter) was used to produce lung phantom using 3D printer technology. A patient-specific 3D-printed lung phantom was fabricated by using a 3-D printer (Original Prusa i3 MK3S+ 3D printer, Josef Prusa). Based on the QUASAR™ respiratory motion phantom geometry the phantom was printed with 8 cm diameter, 15 cm length. Besides the target is centered to the middle of the fabricated phantom with a mass density of 1.2 g/cm3 and Hounsfield Unit value of 68 HU. The surrounding tumor tissue is infill by PLA composite with a 30% infill density and -655 HU of surrounding tissue. The phantoms were splitted into half in order to measure 2-D dose delivery by inserting Gafchromic film dosimetry. Based 4-D CT construction ITV was delineated on 30%-70% of breathing phases. VMAT planning was used for treatment and selected 30%-70% of the breathing cycle as the gating window. As an application of the 3D printed lung phantom, the TPS plan was optimized with Base 30-70 % 10X-FFF and re-calculated with Av-IP (30-70%) 10X-FFF and finally compared with Gafchromic ETB-3 film measured dose.

Results: The measured passing rates of gamma analysis seen to over all 3%/3 mm, 3%/2 mm and 2%/2 criteria, (97,95 and 93 %), (95.6, 92.9 and 91.1 %) and (100,100 and 99.9 %) similar results between Gafchromic ETB-3 Vs Base 30-70 % 10X-FFF, Gafchromic ETB-3 Vs Av-IP: 30-70% 10X-FFF and Av-IP: 30-70% 10X-FFF Vs Base 30-70 % 10X-FFF respectively

Conclusion: It was found that the Dosimetry verification results were extremely similar for both calculated-TPS plan Vs Gafchromic ETB-3 film systems.

Commissioning of Elekta Unity MR-Linac and beam validation of Monaco Treatment planning System model: A single institution experience

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Prospective/Objective: The purpose of this study was the commissioning of the Elekta unity MR-Linac installed at ASST Spedali Civili, Brescia and beam validation of Monaco treatment planning system model.

Materials and methods: Dosimetry measurements and Mechanical tests were performed on an MR-Linac using a different detectors. Dosimetry measurement consisted of comparison between measured and calculated PDDs and profiles, measuring beam quality, reference dosimetry and correlation between CT numbers Vs RED curve. Mechanical test included: MLC transmission, measurement of radiation isocentre diameter, Gantry angle accuracy and MR to MV Coincidence. Measurement devices included Semi flex 3D (PTW 31021), microdiamond (PTW 60019), and Farmer-type (PTW 30013) detectors in an Elekta PTW MP1 water phantom. PTW MP1 scanning water phantom was used to measure depth dose curves and profiles for various depths and for field sizes between 1 x 1 cm2 and 57 x 22 cm2 for an Elekta MR-linac beam with the perpendicular 1.5 T magnetic field. Gammex phantom was also used to correlate CT numbers Vs RED curve in the treatment planning system.

Results: Gantry angle accuracy was within < 0.3 °, the measured radiation isocentre was < 0.5 mm and the coincidence between MR and MV isocentre was -0.14(x), -0.61 (y) and -1.36 (z) mm which is accounted for in the treatment planning system (TPS). The TPR20, 10 was measured, as it is an adequate beam quality specifier for the MR-Linac beam. Gamma analysis is used to assess the agreement between calculation and measurement of dose distribution. Excellent agreements were obtained between calculated and measured dose distribution interims of percentage gamma passing rate criteria. The average gamma passing rate was 98% for profiles and 100% for PDD curves, considering 2% dose difference and 2mm distance to agreement as acceptance criteria. When we used 2 mm distance-to-agreement and 1% dose difference, the agreement between the TPS model and measured scan data showed a satisfactory level of agreement. 30.9% of profiles completely pass the chosen criteria, the analysis of remaining 69% of the profiles demonstrates that measurement error becomes a limiting factor in achieving a better score and 85.7% PDDs curves pass the chosen criteria.

Conclusion: As a result, Commissioning of Elekta Unity MR-Linac and beam validation of the Monaco treatment planning system model for the first time at AAST Spedali Civlili of Brescia is suitable for clinical use.

Implementation of quality assurance for a High Dose Rate brachytherapy system in the clinical environment

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Prospective/Objective: This work focuses on the overall quality assurance of HDR brachytherapy system during: acceptance of the afterloader, source exchange and treatment, including HDR brachytherapy source strength determination and implementation of those quality assurance in the clinical environment.

Materials and methods: Safety quality control testing of HDR brachytherapy system were performed within and around the treatment room. Some selected frequency and tolerances of these safety and physical checks have been assessed. Five measurements were performed in order to ensure the accuracy of source dwell position by source position check ruler and the results were analyzed by imageJ software. To determine linearity of the timer, we collected charges on the electrometer at a fixed measurement position with varying dwell times, for 5, 10, 20, 40 and 80 seconds, the measurements were described graphically by plotting the reading versus dwell time graph. A sheet of Gafchromic film was used for assessment of the offset of some gynecological applicators. To determine the maximum sensitive point of the well-type ionization chamber, the source was moved from top of well chamber with a step size of 1 mm inside the source holder and a set of three measurements for each of the 21 selected dwell positions was taken. The reading (in nA) were tabulated and scattering contribution was assessed by placing the chamber in different scattering effect environment. Reference air kerma rate was determined by sending the source out to maximum sensitive position of the chamber and measurement value was compared with the expected value. During source exchange, a contamination test was also performed by wipe test. Finally, the relevant QA values are used within the treatment planning system.

Results: We found that the nominal and the measured source positions were accurately matched with a difference of less than 1 mm. Offset of applicators obtained in this work is the same with the values given by the vendor, with less than a half millimeter difference. Correlation between programmed times and acquired charges showed good linearity and the measurement was reproducible. The percentage of difference between reference air kerma rate measured with electrometer timer and machine timer is 0.1 % and 0.2 % which indicates the timer is accurate. Both measured values have 0.9% and 1.3% difference from the expected values, within 3% of tolerance in the determination of reference air kerma rate.

Conclusion: The results shows that the source is positioned accurately at expected dwell position. The offset for all the considered gynecological applicators matches the value given by the vendor, that is used in TPS. The timer has a good linearity and is also accurate. All other tests passed and were within acceptable tolerance levels. The performance of all these tests guarantees a proper and safe delivery of the radiation dose.

Dosimetric Study of Fetal Dose during External Beam Radiotherapy using OSLD

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Prospective/Objective: In the Nuclear Medicine department of the Spedali Civili di Brescia, therapy with Lutathera has been performed on 31 patients in the period between November 2019 and October 2022. Patients are released from hospital when their radiation exposure is below established radioprotection levels. The recommendations given to the patient are based on the principle that the radiation dose to people should be kept as low as reasonably achievable. The aim of this study is to evaluate if there is a correlation between the location of the different lesions of the patients and the exposure rate at 1 m.

Materials and methods: The recommended treatment regimen with Lutathera consists of four separate infusions of 7400 MBq each one. The Lutathera protocol requires SPECT-CT images taken at 24, 48 and 120 hours after the administration, always on the same gamma camera. The equipment used was Discovery 670 GE SPECT-CT system. The image correction is done using the algorithm IRACSC (iterative reconstruction attenuation and scatter correction and MIP (maximum intensity projection). For release the patient, dose rate measurements are taken at 1 m and 30 cm from the front of the mid-abdomen of the patients using a Geiger counter. Usually, when the average dose rate at 1 m is less than 5 µSv/h, the patient is released from hospital. The internal dosimetry of OAR (organ at risk) and tumor lesions was performed with the MIRD (Medical Internal Radiation Dosimetry) average dose method, using the ImageJ, Pet-Ct Viewer and homemade plugins and the radiation dose assessment software OLINDA/EXM.

Results: It was found that there is a weak positive correlation between exposure rate at 1 m and anatomical localization of lesion when lesions are in the abdomen, a moderate positive correlation for lesions in the pelvis and a strong positive correlation with lesions present in the other regions (head, arms, and legs). While there is no correlation with the lesions located in thorax and column. Regarding the patient's response to therapy, according to the RECIST criteria, 88.89% of the patients present a stable disease, while 11.11% of the patients have a partial response. The average volume diminution of the lesions 17%. The mean dose to lesions was 89.25 Gy (min = 0.42 Gy, max = 905.56 Gy) and the mean dose to kidney was 3.62 Gy (min = 1.30 Gy, max = 4.73 Gy).

Conclusion: RPT with Lutathera results as a valid therapy, with a stable disease response to the therapy which is favorable for patients with an advanced state of cancer. On the other side, the anatomical localization of the lesions is not correlated with the exposure rate measured using external radiation detector.

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Multicentre intercomparison of semi-quantification in neuro-imaging

Prospective/Objective: Brain imaging with DaTSCAN (Ioflupane I-123) is used to detect loss of functional dopaminergic neuron terminals in the striatum of patients with clinically uncertain parkinsonian syndromes. The uptake of this striatum is semi-quantitatively evaluated with VOI techniques. In this work, a standardization procedure of the acquisition and processing of DaTSCAN imaging between the different centers member of the Italian Neuroscience and Rehabilitation Network (Rete Italiana delle Neuroscienze edella Riabilitazione, RIN) was performed.

Materials and methods: The free software BasGanv2 was employed to assess the specific binding ratio (SBR) in the striatal sub-structures: caudate nucleus and putamen. This parameter was used to compute the recovery coefficient (RC), defined as the ratio of the true and the measured SBRs. Data were collected from 9 centers: 3 of them with SIEMENS and 6 with GE SPECT systems. In each center, images of a Striatal Phantom (with 4 different striatal to background ratios) were acquired following standard protocols. Two methods of tomographic reconstructions were studied: Filtered Back-Projection (FBP) and Ordered-Subsets Expectation-Maximization (OSEM). Analysis on the application of attenuation correction (AC) with the use of LEHR collimators was also performed with the acquisition of images of a cylindrical phantom.

Results: Differences in the processing software of these two vendors (SIEMENS and GE) were found. An optimization of the reconstruction parameters was performed for both systems: FBP with Butterworth filter with 0.45 Nyquist and order 10 for SIEMENS and its equivalent 0.68 cycles/cm and power 20 for GE; OSEM with 10 iterations and 10 sub-sets, using a Gaussian filter of 5 mm for SIEMENS and 1.42 pixel for GE. For both methods, attenuation correction and scatter correction were not applied. The results showed that, when using OSEM reconstruction, the RCs obtained for the SIEMENS SPECT systems are slightly higher than those obtained with the GE SPECT systems. When using FBP, the BasGanv2 software showed limitations in the image processing. Therefore, further investigations have to be carried out.

Conclusion: The presented standardization procedure was demonstrated to obtain comparable results between these RIN centers. o obtain comparable results between these RIN centers.

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Geometric accuracy comparison between three different C-arm LINAC for Radiotherapy

Prospective/Objective: Radiation therapy requires clinical linear accelerators to be mechanically and dosimetrically calibrated to a high standard. One important quality assurance test is the Winston-Lutz test which localizes the radiation isocentre of the linac. The delivery accuracy of highly conformal dose distributions generated using IMRT is strictly related to geometry accuracy of collimator, gantry, and that have many degrees of freedom is directly affected by the quality of the alignment between the radiation beam and the mechanical axes of a linear accelerator. For this purpose, quality control (QC) guidelines recommend a tolerance of ±1 mm for the coincidence of the radiation and mechanical isocenters. Traditional QC methods for assessment of radiation and mechanical axes alignment (based on pointer alignment) are time consuming and complex tasks that provide limited accuracy. The purpose of this work is to evaluate and compare geometric accuracy for three different C-arm LINAC, analyzing the results of the Winston-Lutz test performed for each accelerator and also checking and comparing the isocenter accuracy of integrated imaging system.

Materials and methods: Study included two parts: one related to isocenter accuracy of integrated imaging systems (OBI and EPID: On Board Imaging System and External Portal Imaging System), and one related to radiation isocenter accuracy (Winston-Lutz test); both these parts are phantom based evaluation accomplished analyzing images realized in many different geometric conditions; for isocenter accuracy of integrated imaging systems, the Varian Marker Block Phantom, a plastic phantom has been used, this phantom contains one fiducial marker at the center and four other markers at known locations; for the Winston-Lutz test, the BrainLab Frameless SRS QA target pointer has been used. Both phantoms have been placed at LINACs isocenter according to the field light crosshair projections. Measurements were performed on three Varian machines: True Beam, DHX and C600 (in the last one there is only one imaging system: EPID).The images acquired were analyzed with the image-j free software or directly with the off-line review viewer included within the Treatment Planning System (TPS) in use (Aria/Eclipse vr-15.6 from Varian Medical System).

Results: We compare the mechanical performance between the LINACs and according with the international recommendation mostly from AAPM Reports 142 and 198, other than vendor specifications and tolerance, considering basic and stereotactic requirements, Obtained results were in the acceptable basic tolerance (2 mm) except for the oldest C600, currently used only for few palliative treatments a day; the newest True Beam LINAC showed the best mechanical performance according to both basic and stereotactic requirement (1 mm) and is currently used for this kind of treatment; the remaining DHX satisfied basic requirements but not strictly the stereotactic one, and is used mainly for standard fractionation treatments.

Conclusion: We have proposed an end-to-end IGRT test that accurately and rapidly meets the requirements of TG-142 and follows the workflow of clinical IGRT practice, analyzing separately imaging system and radiation isocenter accuracy. We propose these procedures like practical test with a recommendation to introduce this kind of quality evaluation especially for LINACs used for stereotactic treatments.

Commissioning of in vivo dosimetry using an Electronic Portal Imaging Device

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Prospective/Objective: To leverage the verification system in radiation therapy by implementing in vivo dosimetry measurements using an EPID to prospectively analyze the transit images generated during treatment and estimate the dose delivered using point backprojection.

Materials and methods: An amorphous Silicon (a-Si) electronic portal imaging device (EPID) iViewGT was used for the commissioning of EPID in vivo dosimetry (EIVD). The dose is reconstructed using backprojection of the EPID signal. The signal collected by the EPID from the radiation passing through the patient (transit condition) is converted into an image, which is corrected for noise and non-homogeneous gains in the EPID's pixels.The dose is reconstructed using the point backprojection formalism: using conversion factors of EPID signal to absolute dose at EPID level, the dose for non transit conditions at EPID level is then calculated with finite tissue maximum ratios (FTMR), the maximum dose at SAD level is further calculated by using the inverse squared distance relationship, and finally, the dose at the point of interest is calculated using TMR factors. The conversion factors and FTMR factors were acquired by a combination of EPID and chamber measurements in non-transit conditions and in transit conditions, for various field sizes and phantom's thickness. The dose is calculated at a point in the planning tomography provided by the TPS, in this case Monaco's 6.0

Results: A model for dose reconstruction from EPID images of 6 MV photons was built, which is capable of calculating the dose to the isocenter of an homogeneous phantom with an accuracy under 0.55% for open fields. The dose reconstruction was evaluated along the central axis in a clinical relevant range of (3 - 20) cm, and found to be under a 2.5% of relative deviation from the dose calculated using. Additionally, the dose outside the central axis was assessed, in a radius of 9 cm and in a radius of 6 cm; the dose reconstruction relative deviation was under 5.8% and 2.84% respectively. The RMSE was evaluated for all off-axis measurements, with a maximum value of 6.62 for a dose range of (61-480), measured at different depths.

Conclusion: EIVD commissioning process and daily set-up is rather simple and little time consuming, furthermore, it provides an efficient and accurate assessment that can be implemented in the routinely practice to detect errors that otherwise would not be detected by pre-treatment quality assurance verifications.

Clinical validation of an automatic image segmentation system based on deep learning for its integration in the head and neck radiotherapy workflow

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Prospective/Objective: Image segmentation of organs at risk (OAR) is a focal point of the radiotherapy planning (RT) workflow with implications on the overall quality of the radiotherapy process, including plan optimization/evaluation and dose delivery. Up to now, contouring requires large amount of human resources because it relies mainly on manual delineations which is time expensive and operator-dependent. Inter-intra-operator variability, lack of standardization are common issues of manual contouring. Automatic tools have the potential to address these flaws improving the efficiency of the procedure. The study aim was to validate the Raystation automatic image segmentation module based on Deep Learning (DL) via 3D-Convolutional Neural Network and U-Net architecture. The head and neck anatomical site (HN) was chosen for the purpose of validation with the following endpoints: a) to assess the quality of the automatic image segmentation through comparison with manual segmented ROIs from clinically delivered plans; b) to investigate the impact of the geometric uncertainties, originated from the mismatch between the automatic and manual contoured ROIs, on the overall plan quality in terms of target dose coverage and OARs

Materials and methods: CT planning datasets, including RT plans and RT structures, from a cohort of 24 HN patients, treated from 2018 until 2022 at the University Hospital of Novara, have been used. A total number of 496 manual segmented ROIs were available to generate the ground truth scenario used for the purpose of the DL auto-segmentation validation. The contours generated by the DL tool were compared to the reference ones by means of overlap metrics, the Dice Similarity Index (DSC), and distance metrics including Hausdorff Distance (HD), the 95th percentile of Hausdorff Distance (HD95) and Average Hausdorff Distance (AHD). The impact of OAR segmentation errors on dose distribution has been investigated evaluating the difference of the dose delivered to the targets and manually contoured OARs reoptimizing the original plan with the automatic contoured ROIs. Target coverage, maximum and mean dose differences have been computed for each structure. Linear generalized methods, logistic regression and ROC curves have been used to evaluate the relationship between the contour disagreement measured by AHD metrics and the dose increments to OARs.

Results: Good agreement was achieved for the majority of the segmented ROIs with DSC values higher than 0.75 and AHD comparable with the image voxel size (1x1x2 mm3). Moreover, our findings were in line with the literature benchmarks obtained from auto-segmentation challenges. HD95 highlighted significant discrepancies at the extremities of tubular organs due to low contrast images and failures depending from artifacts. AHD values > 2.5 mm were related to mean overdosages to OARs > 2.5 Gy. Target coverage was independent from the segmentation agreement.

Conclusion: The DL-based auto-segmentation was validated in the HN site: The agreement with the gold standard was within inter-operator variability. AHD was a valuable prognostic factor for plan dose distribution degradation originated by segmentation errors.

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Commissioning of modern Treatment Planning System (TPS) for nuclear medicine therapy using standardized virtual phantoms

Prospective/Objective: TPSs have been recently introduced to personalize the internal radiation therapy, unfortunately, there are no harmonization or guidelines on commissioning these tools. The aim of this study is to assess the discrepancies among three TPSs developed for radioembolization with 90Y in terms of volumes of interest (VOIs) and dose metrics, i.e., mean absorbed dose and Dose Volume Histograms (DVHs).

Materials and methods: We used five (i.e., two experimental and three virtual) phantoms imported within three TPSs (Dosisoft, MIM, and Simplicity) used for 90Y dosimetry. The experimental phantoms were acquired with SPECT/CT D670NM/CT (GE) and filled with 99mTc-pertechnetate. The virtual phantoms assuming to be filled with 90Y were generated by MATLAB script and saved into DICOM format. NEMA homogeneous and kernel phantoms contained the following VOIs: body, body-1cm, target-2cm and target-1cm. The anthropomorphic phantom included the whole body, liver, and hot and cold spheres. Each TPS extracted the volumes of VOIs in ml. Three methods were used for voxel-based dosimetry calculations within the TPSs: the local deposition method (LDM), the LDM with scaling for known injected activity (LDMwS), and the dose kernel convolution (DKC) method. Simplicity used only the LDM approach, while MIM used the LDMwS one. LDM and DKC were applied to the Dosisoft software. The calculated volumes and dose metrics were exported using the TPSs or manually in a few cases. All the Bland-Altman plots and statistical results were calculated using RStudio software.

Results: There were no differences in volumes of VOIs for kernel and homogeneous virtual phantoms when evaluated within the same TPS. Differences up to 5% between homogeneous virtual phantom and experimental one and trivial differences between anthropomorphic virtual and experimental one were found. The difference of the mean absorbed dose for Kernel Phantom obtained from different TPSs for the same VOI was up to 50%, while the absorbed dose range varied between 0 Gy to 75000 Gy. The range of the mean absorbed dose for homogenous phantom was between 3 to 5.1 Gy. Concerning the two anthropomorphic phantoms, the dose difference was up to 10 times for the cold sphere, where the absorbed dose range of virtual phantom was shifted 100 Gy higher than the experimental one. The DVHs were different for homogeneous and anthropomorphic (virtual and experimental) phantoms due to the image noise and likely the low resolution of the experimental images. Besides the kernel phantoms, the DVH was generated, assuming that the administered activity was located inside a voxel. The Bland-Altman plots showed discrepancies for each VOI volume up to 25% and 10% for homogeneous and anthropomorphic phantom, respectively. In addition, the Bland-Altman plots comparing the mean absorbed doses of VOIs showed discrepancies up to 20% for the virtual phantoms and up to 10% for the experimental phantoms.

Conclusion: Significant discrepancies in calculated absorbed mean doses were found using the investigated TPSs. Further investigations are recommended using other radionuclides and TPSs.

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Evaluating the effect on Hounsfield Units reproducibility with different algorithms in a dedicated radiation therapy CT scanner and its effect in detectability and dose.

Prospective/Objective: In a CT scan, Hounsfield Unit is proportional to the degree of x-ray attenuation and is allocated to each pixel to show the image representing the tissue's density. Currently, CT scanners provide several reconstruction algorithms to address specific issues during CT imaging.We aimed to assess the change of computerized tomography attenuation (Hounsfield unit-HU) for different materials of known electron density within a wide range, using these available post-processing algorithms. We considered different iterative algorithms for Metal Artifact Reduction (iMAR), used to reduce the metal artifact effect, and Direct Density algorithms used to perform the easy dose calculation from the HU values at one artificial-kV instead of many different original kV values. These algorithms are provided by the manufacturer at the installed Siemens Dual Energy Syngo CT.

Materials and methods: In this prospective study, the Gammex 467 phantom consists of a 33 cm diameter Solid Water disk approximating the size of an average pelvis (330 mm × 50mm ×H). The phantom was equipped with different tissue surrogate inserts and three different metal inserts of Aluminum, Titanium, and Steel. Image analysis was performed using Image J. Mean CT numbers and the standard deviation of the inserts were measured within the regions of interest (ROIs) in the inserts. The dose calculation was carried out in the Varian Treatment Planning System within the box plan with a cube digital phantom sized (20x20x20) and each field size 10x10.

Results: This study shows that for different iMAR algorithms (8 algorithms specific for 8 clinical situations metal implants), the HU variations have the same trend toward the electron density of different human tissue surrogates, but the amount of these differences is changing over the metal inserts used: in detail, it appears that the iMAR algorithms introduce an underestimation of the HU for low electron densities materials while an overestimation for high densities and also that these variations are more significant, in terms of CNR, as the density of the metal, that produces the artifact, is higher. In the scan without metal inserts, the iMAR algorithms don’t bring any significant difference which instead is highlighted with the metal inserts, showing that the amount of HU change is dependent on the strength of these inserts. For the study of the Direct Density algorithm the calculated dose difference using the artificial 120 kV compared to the actual 120 kV scan, is almost negligible for soft tissue but for tissue with a higher density, like bone, there is a difference within 3%

Conclusion: Thus, from this study we concluded that although the algorithms described are of undoubted utility, their effect can lead to differences in the “output” which can produce errors, to be considered especially in processes based on an automated quantitative image evaluation or dose calculation based on tissue characterization.

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A **systematic approach to identify the optimal input parameters of Personalized Planning.**

Prospective/Objective: The main objective of the work is to evaluate the impact of different parameters in the new Pinnacle Evolution (version 16.4.3) by comparing it with their respective clinically accepted reference treatment plans. The plans were assessed according to the dosimetric parameters and monitor units.

Materials and methods: Two different clinical cases, i.e., prostate and head & neck, were treated with volumetric modulated arc therapy. Thirty-three plans were optimized for each clinical case: the clinically accepted reference plans were generated using specific plan parameters derived based on feasibility dose-volume histogram (FDVH) in PlanIQ. For each case, a reference plan was saved as a treatment technique, and before optimization, a single plan parameter was changed to determine its effect on the dose distribution and on the monitor unit amount. The plans were assessed according to the monitor units, dose metrics (i.e., dose volume criteria & DVHs) of both organs at risk (OARs) and Planning Target Volumes (PTVs). The evaluated OARs were the rectum and bladder for the prostate plan and the right parotid, lips and spinal cord for the head and neck plan.

Results: The conversion cycle adjusted to “10” and refinement cycles to “2” and “3” have produced a better plan quality with target coverage met and OARs sparing. Adjusting control MLC modulation to “Yes” spares OARs. Modulation amount parameter adjusted to “very high”, results in fewer monitor units (i.e., 681.2, 709, 743.9, and 699.5, MU for very high, high, medium, and low, respectively). “SRS/SBRT mode”, was effective for head and neck with both OARs sparing and target coverage met. For prostate, only the rectum and bladder mean dose was reduced with “standard fraction mode” compared to “SRS/SBRT mode”. Match target coverage adjusted to “No” showed a significant dose increase for targets and OARs mean dose and dose-volume criteria of both cases. For head and neck “weighting balance” parameter adjusted to “20” produced a better plan with OARs sparing and fewer monitor units (708.9 MUs compared 681.2 MUs). For prostate, weighting balance adjusted to “-20” produced a better plan with target coverage met and fewer monitor units of 977.2 MUs. For prostate target transition falloff rate adjusted to “30” or “40” have produced a better plan with fewer monitor units of 997.2 and 977.6 MUs, respectively. For head and neck target transition set to “40” spared right parotid and with fewer monitor units of 681.2 MUs. Target edge weight adjusted to “2” demonstrated to be the best choice for prostate and head and neck for OARs sparing.

Conclusion: The results indicate that parameter selection in Personalized Planning plays a vital role in improving the quality of treatment plans. It is concluded from the results that the dose variations with the change of input parameters are significant. The impact is greatest on the rectum, and right parotid mean dose of prostate and head & neck, respectively.

Implementation of Code of Practice for Quality Assurance Program in High Dose Rate Brachytherapy with Ir-192 source

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Prospective/Objective: To develop and implement the code of practice for Quality Assurance (QA) program in Brachytherapy (BT) with Ir-192 source. Because of the existence of variable BT equipment, AAPM TG-56 recommended each clinic to develop a dedicated QA program that suites its brachytherapy machine. In this thesis work, the code of practice for QA was written and implemented at Modena University Hospital aiming to assure accurate operation of BT equipment with a major focus on security controls, geometrical and dosimetrical measurements and to verify safety conditions for radiation protection purposes as required by national regulations. Multichannel applicators were commissioned to establish its baseline operating performance.

Materials and methods: Following the guidelines (IAEA TECDOC-1274, AAPM TG56, and GEC-ESTRO booklet-8), the code of practice for QA in BT was developed for microSelectron HDR-V3 unit and OnCentra treatment plan system (TPS). Transfer tubes, well type chamber, electrometer, Gafchromic films, check ruler, set of applicators and film scanner were used for source calibration and for commissioning of Multichannel applicator. For radiation protection purposes, a calibrated Automess (6150 Ad-B) was employed to verify the existing shielding and to check the leakage radiation. An end-to-end test was performed by using Gafchromic films that were placed within Multichannel applicator in a solid PMMA water equivalent phantom. By means of 2D-gamma analysis, films dose maps were compared to RTDoses from the OnCentra TPS after being loaded into PTW-Verisoft software.

Results: The results from the source calibration showed optimal agreement between the measured air kerma rate (source strength) and the value of source certificate with a difference of 1.82% and the measured source positions were within ±0.2 mm on average from the expected positions. The radiation protection results were in agreement with recommended limits, and the highest annual equivalence dose rate evaluated was 0.154 mSv/year in controlled areas. Results of first source positions for all Multichannel transfer tubes and needles evaluated were in agreement with respect to declared values, with a maximum difference of ±0.5 mm. Gamma passing rate calculated between film and RTDose maps was 100% for the intrauterine VT and was 91.8% for needle-10, with 3%/3mm criteria.

Conclusion: Results showed that the status of the machine and its components ensured an acceptable clinical outcome. The deviation in source activity was less than the recommended tolerance limit 5%, uncertainties in source positions are less than 1mm and agreed with the GEC ESTRO (2004) recommendations. The walls bunker shielding were still suitable according to national regulations. The end-to-end results guarantee the correct dose delivery to patient.

Impact of data-driven respiratory gating algorithm on small lesions in PET/CT imaging.

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Prospective/Objective: Respiratory motion induces artifacts in PET/CT imaging that may introduce significant image distortion, and an important cause of diagnostic uncertainty, particularly for lesions located in the lung/diaphragm interface.Our primary objective was to assess the effects of a data-driven respiratory gating (DDG) algorithm on lesion maximum standardized uptake value (SUVmax) and volume for small lesions with low and moderately low target-to-background ratios.

Materials and methods: We used the QUASARTM Programmable Respiratory Motion Phantom, which is designed to move cylindrical inserts in the superior-inferior direction within a torso shaped acrylic oval varying both speed and amplitudes.We have built an insert compatible with Quasar phantom motion platform that allows the simulation of the background. The insert was filled with water to simulate the liver density (~1.07 g/cm3) and with water and polystyrene beads to mimic lung density (~ 0.3 g/cm3). We placed inside the insert a glass sphere with 13 mm inner diameter to represent a small tumor. Both insert and sphere were filled with 18F-FDG solutions of different concentrations to attain different target-to-background ratios. For the acquisitions, we used the Whole Body PET/CT protocol that includes the Q.Static acquisition mode, in which an automated motion correction technique is integrated. DDG-PET data were derived from a portion of the total PET data (~50%) in the end-expiration (EE) phase at 30% offset from the end-inspiration (EI) phase of each respiratory cycle. We investigated effects of data-driven respiratory gating algorithm on lesion maximum standardized uptake value (SUVmax) and volume by comparing DDG-PET images and non-gated PET images, both reconstructed with two available algorithms: VUE Point FX (VP) and Q.Clear (QC).

Results: For the 3:1 target-to-background ratio (TBR), the motion correction with DDG PET increased the lesion SUVmax by the average of 25 ± 13% for VP and 26 ± 17% for QC. The lesion volume decreased by 35 ± 15% for VP and 31 ± 36% for QC. For 3:1 TBR lung case, the motion correction with DDG PET increased the lesion SUVmax by the average of 26 ± 10% for VP and 27 ± 17% for QC. The lesion volume decreased by 31 ± 40% for VP and 27 ± 32% for QC. In these cases, the average was done over 4, 6, 8 and 10 mm motion amplitudes. For the 4:1 TBR, the motion correction with DDG-PET increased the lesion SUVmax by the average of 28 ± 12% for VP and 33 ± 12% for QC. The lesion volume decreased by 39 ± 13% for VP and 39 ± 10% for QC. In this case the average was done over 4, 6, 8, 10, 12 and 15 mm motion amplitudes.

Conclusion: Application of DDG was found to significantly increase the lesion SUVmax and decrease its volume with respect to non-gated images, by mitigating the blurring effects of respiratory motion, and to give more accurate representations of uptake as well.

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aaImage quantification and analysis of SPECT DaTscanTM examinations of patients with suspected Parkinson's disease through two 3-D automatic tools

Prospective/Objective: This work reports a head-to-head comparison on the quantification of two software, BasGanV2 and Datquant®, of DaTscanTM radio-tracer uptake in brain striatum regions through the correlation between quantification metrics, and the decision of these metrics towards isolating patients with Parkinson's disease (PD) from the sample with visual reading by the physician (the gold standard, GS). The metrics include specific binding ratio (SBR), putamen-to-caudate ratio (PCR), caudate-to-putamen ratio (CPR) and asymmetry indices (AI).

Materials and methods: The study analyzed 112 patients who underwent brain DAT (Dopamine active Transporter) SPECT imaging with DaTscanTM for a suspected parkinsonism. The post-processing of brain DAT images was performed using the two software for quantification purpose. The Bland-Altman analysis was used to reveal the mean bias between the two methods, while for instance the areas under ROC (receiver operating characteristic) curves (AUCs) of SBR values were utilized to measure the diagnostic accuracy of the metrics.

Results: The study found a significant correlation between the two software for each semi-quantification parameter. The correlation coefficients, r, ranges from 0.684 to 0.962. Among others, a strong correlation was observed for SBR values with, r = 0.962, 0.9477, 0.9474, 0.946, respectively, for left putamen, left caudate, right caudate and right putamen SBRs. Furthermore, with BasGanV2 quantification, out of 112 patients, 74 (66.07 %) had PD and 38 (33.93 %) were normal, while with Datquant®, 68 patients (60.7 %) were positive to PD and 44 (39.3 %) were healthy patients. The GS confirmed PD in 64 patients (57.14 %) and 48 patients (42.86 %) were found normal. The PD diagnostic agreements between BasGanV2 and Datquant® software and doctor's decision, were, respectively, 85.71 % and 83.92 %. In addition, AUCs showed that the two tools offer a PD diagnosis to about 95.20-99.99 %.

Conclusion: All semi-quantitative metrics showed a significant correlation between Datquant® and BasGanV2 and higher values of AUCs support the accurate PD diagnosis with these tools. Along with this, the mean bias observed between the two methods, hints out that none of them is preferred over the other.

Dosimetric commissioning of VMAT treatment on a Linac after a major MLC upgrade

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Prospective/Objective: The complex dose distributions of the VMAT technique increase the importance of accurate beam data measurements and review in the commissioning process. In this work, a Synergy linac, containing a beam modulator MLC collimator gets upgraded with an Agility MLC. The aim of the present study is focused on the dosimetric commissioning and validation of the updated linac for 6MV photon beams and VMAT treatments as well as describing general concepts, regarding beam modeling in the TPS and dose verification before clinical use.

Materials and methods: For the dosimetric measurements of acquiring beam data of a Monte Carlo based TPS, “Monaco”, a watertank was used, which can measure the dose distribution in all directions to obtain PDDs and profiles accurately, with the advantage that water mimics the radiation properties of human tissue. Beam modeling was done with special test beams, analyzing different parameters of the MLC’s that can be optimized inside the TPS. These test beams were measured on a cylindrical phantom, a Delta4 WiFi, offering the analysis of 3D dose distributions. VMAT plans were calculated and optimized following the AAPM TG119 for dose prescriptions, planning objectives and dose verification. AAPM TG119 report presents guidelines from a dosimetric study, to facilitate and ensure the accuracy after commissioning processes for modulated techniques, proposing mock test plans with dedicated phantoms. An on board Epid and two cylindrical phantoms; the Delta4- and Matrix phantom were used for comparison of 2D/3D dose distributions, the Matrix was used for 1D single point absolute dose verification. The comparison of measured and calculated dose was done by using a global gamma criteria of 3%/3mm as well as 2%/2mm (10% cut of). Confidence limits (CL) were generated and compared with the TG119. Lastly, 20 clinical plans were irradiated with the updated linac, using the Delta4 and Epid for comparison of dose distributions. The interchanging between this linac and two other linacs with the same dosimetry was also tested.

Results: Measurements for verification of the TPS dosimetric model received from the manufacturer concluded that it was necessary to modify the Leaf Groove Width from 0 to 1mm, to obtain an acceptable match between calculated and measured dose distribution. The overall passing rate for the TG119 mock plans, using the 3%/3mm gamma criteria for the Delta4 and Epid were 99.8%±0.12 (CL 0.47) and 97.4%±0.24 (CL 3.1), respectively, and with the 2%/2mm gamma, they were 97.5%±1.3 and 95.6%±0.49. While measuring the 20 clinical plans with the Delta4 and Epid, at the reference QA criterion of 3%/3mm, the gamma passing rates were all above 97.7% and 94.7%, respectively. When the tolerances became stricter with 2%/2mm, the gamma passing rates were all above 90 % for the Delta4 and 85.1% for the Epid, which is still considered acceptable. The absolute dose measurements with the Matrix resulted in a mean difference of 1.3% with a standard deviation of 1.23. The interchanging between linacs showed differences in gamma passing rates ≤ 0.3%.

Conclusion: TG119 methodology and recommendations have successfully been used to evaluate commissioning accuracy of VMAT plans and the obtained data were found within the limits of TG119. After completing all the measurements described in this work and being satisfied with the results, this upgraded linac was ready to be used clinically.

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Dosimetric Comparison of 3-Dimensional Conformal Radio-Therapy (3D-CRT), Volumetric Modulated Arc Therapy (VMAT), and Hybrid Volumetric Modulated Arc Therapy (H-VMAT) Techniques for Left Breast Cancer

Prospective/Objective: The aim of this study was to evaluate 3D-CRT, VMAT and Hybrid Volumetric Modulated Arc Therapy (H-VMAT) techniques for left breast cancer treatments. Dose homogeneity and conformity of the Planning Target Volume (PTV) and organs at risk (OAR) sparing were evaluated, as well as the plan's robustness against rigid patient shifts. The study was conducted in Azienda Ospedaliero Universitaria delle Marche (Ancona, Italy).

Materials and methods: We considered patients who underwent left-breast after-surgery radiation therapy with a dose of 40.05 Gy in 15 fractions prescribed to the whole breast, with no boost to the surgical bed. Seven patients treated with 3D-CRT plans were selected with the following criteria: D2% < 107% and D98% > 90% for PTV, V16Gy < 20% for left lung, V8Gy < 20% for heart and Dmean < 20Gy for the Left Anterior Descending artery (LAD). Concurrent VMAT plans (Eclipse RapidArc®) were optimized imposing OARs constraints equal to the 3D outcomes. Were used three different treatment techniques, Two tangential opposing open fields were used for 3D-CRT with field in field, three half arcs were used for VMAT, and for the H-VMAT (H-VMAT1a and H-VMAT2a), two tangential opposing open fields were used for the 3D-CRT part 80% of prescription, and one and two half arcs were used for the VMAT part with 20% of prescription. This should be finished for future clinical implementation of Breast cancer treatment. Moreover, only setup uncertainties in the ±5 LL direction were included for evaluating the plan's robustness.

Results: Homogeneity Index (HI) mean value for H-VMAT 2a (0.07±0.01) was improved respect to H-VMAT 1a (0.10±0.02), VMAT (0.10±0.02) and 3D-CRT (0.12±0.01) with a p-value p<0.03 among all techniques. No statistical difference was found between H-VMAT 1a and VMAT (p=0.8).As expected, VMAT provided the highest conformity to target, with a Conformal Number (CN) mean value of 0.89±0.01 for the isodose 95%. Conformity for both H-VMAT solutions was characterized by a mean value of 0.86±0.04, which was very close to VMAT outcome. No statistical difference was found between H-VMAT with one and two arcs (p=0.8). CN of 3D-CRT was 0.75±0.04. Left Lung V16Gy for VMAT (10.1±4.1 %), H-VMAT 1a (12.3±5.7 %) and H-VMAT 2a (12.0±5.7 %) showed a negligible difference with 3D-CRT outcome (0.09<p<0.22). In the low dose region of the DVH, a decrease of the irradiated volume V4Gy was observed for H-VMAT 1a (34.9±5.9 %) and H-VMAT 2a (33.4±5.2 %) respect to VMAT (39.7±7.0 %). Contralateral lung and breast received an evident dosimetric advantage with the use of Hybrid techniques respect to VMAT plans. We found a mean dose value of 298±22, 49±13 and 87±13 cGy for right lung and 358±35, 80±25 and 143±23 cGy for right breast, using VMAT, HVMAT 1a and HVMAT 2a, respectively. Right lung low dose bath was characterised with V5Gy values never exceeding 1.2% for all H-VMAT plans, against a mean value of 16.2±5.2 % for VMAT. Compared to 3D-CRT dosimetry, H-VMAT outcomes for contralateral lung and breast should be a negligible source of clinical concern, especially if one arc is used. Mean dose value of heart in 3D-CRT technique was (124.93±34.25 cGy), in VMAT technique (292.89±55.58 cGy), H-VMAT 1a (185.14±48.60 cGy) and H-VMAT 2a (182.99±45.28 cGy) techniques. No statistical difference was found between H-VMAT 1a and H-VMAT 2a (p=0.7).LAD mean dose did not show an appreciable difference among all techniques, with an overall mean value of 540±328 cGy. In order to evaluated robustness against setup errors, a shift of ±5mm (IEC1217) in Latero-

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Lateral direction was applied to isocenter. The CTV volumes covered by near minimum and near maximum dose, D98% and D2% respectively, were used for dosimetric evaluation. D2% and D98% values did not change significantly for shifted plans among all techniques ($0.33<p<0.64$).

Conclusion: Basing on our patient selection, we demonstrated that H-VMAT technique was a good trade-off between "pure" VMAT and 3D-CRT plans for left breast treatment. HVMAT provided good homogeneity and conformity to target while preserving heart, contralateral breast and lung. Furthermore, it had a limited impact on planning activity since it did not required any "skin flash" management to ensure robustness against moderate patient shifts.

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SBRT for localized prostate cancer using single arc VMAT: plan quality, complexity, dose delivery accuracy, and efficiency

Prospective/Objective: Plan quality, complexity, dose delivery accuracy and efficiency were compared for low- and intermediate-risk prostate stereotactic body radiation therapy (SBRT) on a C-arm LINAC. Three different volumetric modulated arc therapy (VMAT) arrangements were investigated in order to minimize the treatment time, therefore reducing the intrafraction prostate motion uncertainties, while meeting the clinical objectives.

Materials and methods: A retrospective dataset of 11 patients was used. All plans were designed to deliver 40 Gy in 5 fractions to the prostate planning target volume (PTV) using a VersaHD C-arm linac (Elekta AB, Stockholm, Sweden). Two full arcs 6 MV flattening filter free (FFF) plans were compared to single full arcs using both 6 MV FFF and 10MV FFF. A plan quality index (PQI) was calculated to compare the achievement of treatment goals after optimization. Plan complexity was evaluated with the modulation factor. The dose delivery accuracy and efficiency were investigated with patient-specific quality assurance (PSQA) of all VMAT plans using the Octavius 4D phantom and the 1500 Detector (PTW, Freiburg, Germany).

Results All treatment plans met the planned dose constraints. No statistical differences were found in the PQIs and MUs comparison among the three techniques. The PSQA plans of all three techniques passed the γ criteria of 2%/2 mm with mean γ passing rates > 96.5%. As expected, the techniques using single arcs showed a statistically significant decrease in the delivery time. The mean delivery times were 1.6 min (corresponding to a reduction of -46%) and 1.3 min (with a reduction of -56.2%) for 6 MV FFF and 10 MV FFF respectively.

Conclusion: High-quality plans have been achieved with reasonable complexity using single arcs VMAT for prostate SBRT. The reduction in treatment time, the accuracy and the reproducibility of the dose delivery of single-arc FFF treatments demonstrated that the proposed strategy is feasible for low- and intermediate-risk patients. In particular, the lowest delivery time required for 10MV FFF clearly demonstrated the advantage of this strategy in reducing intrafraction prostate uncertainties.

Evaluation of feasibility of using RayStation treatment planning system as an independent dose calculation system for the Unity MR-linac

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Prospective/Objective: MR-guided radiotherapy (MRgRT) offers advantages over traditional x-ray methods, including enhanced soft-tissue contrast, real-time capabilities, and the ability to adapt treatment plans based on daily MR imaging. While measurement-based patient-specific QA methods are suitable for the Elekta Unity MR-linac, the impracticality of verifying adaptive plans with phantom measurements before treatment calls for a more efficient solution. However, for MR-linacs the dose calculation tends to become complicated with the existence of magnetic field. Therefore, only a few dose/MU check programs for Unity MR-linac were commercially available so far. The primary goal of this thesis is to examine the resemblance of dose distributions, generated by RayStation and Monaco, and to evaluate the feasibility of using RayStation TPS as a secondary dose calculation software for the purposes of MR Unity PSQA. Additionally, the second goal is to evaluate the feasibility of using RayStation as a basis for a measurement-less PSQA approach.

Materials and methods: Since RayStation does not simulate the influence of the magnetic field and has differences in dose calculation algorithms compared to the native Unity TPS (Monaco), two correction approaches were proposed and tested to enhance similarity between these TPS. Twenty clinical cases each for the brain and head & neck were exported to RayStation, and corrections were applied. Subsequently, the corrected dose distributions were compared to the original Monaco plans using gamma analysis, and the results were assessed against AAPM TG 219 recommendations. The correlation and agreement between RayStation and Monaco datasets were evaluated using Pearson Correlation Coefficient calculations and the Bland-Altman plot method. Finally, ten verification plans for both the brain and head & neck were recalculated in RayStation, and the results were compared with ArcCheck measurements to assess theoretical dose distribution similarity with real machine performance.

Results: An optimal 0.13 isocenter shift, both perpendicular to the magnetic field and along the central beam axis, was established to simulate the magnetic field's influence. Four different MU correction methods were proposed to address differences in dose calculation algorithms. The gamma comparison of all 40 plans (RayStation vs Monaco) revealed a passing rate exceeding 90% of points with gamma values ≤1 (3%/2 mm, 10% dose threshold). However, only a limited number of RayStation plans achieved a 90% passing rate in gamma comparison with ArcCheck measurements (RayStation vs ArcCheck). Only negligible correlation was observed between RayStation-related datasets and measurement results. Despite this, RayStation-related datasets demonstrated agreement with the measurements.

Conclusion: While the Bland-Altman plot method demonstrated agreement between RayStation-related datasets and measurements, the lack of correlation with ArcCheck measurements prevents the use of PSQA values of RayStation plans to predict specific measurement results. Despite the established agreement by the Bland-Altman plot method, the relatively high deviation in gamma analysis results (RayStation vs Monaco) widens the predicted range of differences (95% confidence limit), making it impractical for use. Nevertheless, the theoretical dose distributions' similarity between the two TPSs, meeting AAPM TG 219 criteria, supports the introduction of RayStation as an independent dose calculation system for the Unity MR-linac.

End to end verification in gated-treatment delivery: a comparison between motion phantom devices

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Prospective/Objective: to evaluate the impact of gated treatment and non-gated treatment from imaging to delivery and to quantify the impact of gating amplitude on the treatment delivery by means of phantom simulation and measurements.

Materials and methods: To achieve our goals, a CIRS Model 008A Dynamic Thorax Phantom and quasar programmable respiratory motion management phantom (QPRMP) was used. Standard and custom inserts with films were employed to mimic lung motion for end-to-end test measurements within the phantom. Using a Toshiba 16-slice CT scanner, we simulated phantoms and acquired 4DCT datasets by binning respiratory cycles triggered by the Varian RPM system into ten phases. Two plans were created in the Varian Eclipse Treatment Planning System for delivery: one delivered using the gated system (gated plan) and one without it (non-gated plan). The gated treatment plan delineates the target within a single breathing cycle phase, whereas the non-gated plan represents an average of ten static phases for targeting. The treatment plans were compared to evaluate the benefits of gated versus non-gated approaches in managing tumor motion. Radiochromic films EBT3 irradiated inside the moving phantom were used to assess the accuracy and the reproducibility of the treatment.

Results: In both for gating at 10% of the amplitude and 50%, we have a significant dose reduction compared to the non-gated as expected. The gated treatment by reducing the volume of the target spares high-dose spillage to non-target structures and enhancing dose distribution conformity compared to the non-gated. Film measurements showed optimal agreement between the calculated dose and measured dose distribution for gating at 10% of the amplitude with gamma passing ratio of 99, 4%. This value demonstrates the optimal quality for the end-to-end test. Yet, it decreased to 82.1% (failing the gamma test) when the gating amplitude was adjusted to 50%, highlighting the significant impact of gating amplitude on treatment efficacy.

Conclusion: Gated treatment outperforms non-gated approaches in managing tumor motion. However, finding the optimal amplitude is crucial. Smaller amplitudes improve treatment quality but prolong time. Striking a balance is key, ensuring an effective treatment while optimizing time efficiency.

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Commissioning And Quality Assurance Of A New PET/CT

Prospective/Objective: The PET/CT performance has a direct clinical impact. This study evaluated the physical performance of a new SiPM-integrated digital PET/CT scanner, uMI Vista from United Imaging Healthcare, installed in our Institute, comparing the Vendor tool results and free available software.

Materials and methods: Following the NEMA NU-2 2007 standards, and using the specifics phantoms, spatial resolution, sensitivity, scatter fraction, accuracy and image quality tests were evaluated on the PET system. Spatial resolution was assessed by imaging three radioactive point sources in the air. System sensitivity was measured by using a NEMA sensitivity phantom. As described in the standard, we used a solid polyethylene cylinder with a line source positioned parallel to the tomograph axis at a few radial distances to measure the scatter fraction, and image quality was assessed with PET NEMA IEC phantom filling the four smaller spheres with radioactive solution and the two big with non-radioactive water. We processed the NEMA images acquired during the various tests with ImageJ software and compared the results obtained with those given by the manufacturer's software. The image quality and radiation dose were examined as part of the CT acceptance test using CATphan 600, system phantom, and standard PMMA phantom. The tube voltage and the HVL of the X-ray tube were also evaluated using an Unfors multimeter. The CT data have been analysed with IQworks software and Microsoft Excel.

Results: With the Vendor tool, the radial/tangential/axial FWHM were 2.99/2.99/3.03 mm and 5.54/5.24/5.26 mm at 1 and 10 cm off-centre, respectively, while using ImageJ they were 2.96 $\pm$ 0.04/ 3.10 $\pm$ 0.05/ 3.15 $\pm$ 0.05mm and 3.47 $\pm$ 0.025/ 3.22 $\pm$ 0.03/ 3.32 $\pm$ 0.02mm. Sensitivity at centre and 10 cm FOV given by the Vendor tool were 8.998 and 9.001cps/kBq, respectively, while they were very different using ImageJ. The results given by the Vendor tool showed that at a clinically relevant activity concentration of 19.78 kBq/cc of 18F-FDG, a Peak NECR is 122.58 kcps and scatter fraction 38.79%, while the percent error below the peak NECR was 3.03 %. The contrast recovery of 10, 13, 17, 22, 28 and 37 mm sphere diameters given by Vendor tool were 59%, 81.4%, 86.8%, 94.7%, 82.1% and 85.5%, respectively, while the background variability were 4.5%, 3.7%, 2.8%, 2.1%, 1.6% and 1.3%, respectively. ImageJ analysis gave 48%, 66%, 73%, 85%, 84% and 90% for the contrast recovery, and 3.8%, 3.1%, 2.6%, 2.3%, 1.9% and 1.5% for background variability, respectively. The lung error residual mean was 2.8% and 2.9% using the Vendor tool and ImageJ. Finally, the CT image quality and CTDI values resulted in the hospital's acceptance range.

Conclusion:

All the performance tests carried out on our new PET/CT were in the acceptable range given by the manufacturer, and the results of CT scanner were also acceptable for clinical use. This new scanner meets the highest standards of precision and safety and it opens new possibilities for patient diagnostic and treatment in our hospital.

Analysis and validation of the TQA quality assurance system in tomotherapy

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Prospective/Objective: Tomotherapy combines the precision of intensity-modulated radiation therapy (IMRT) with the geometric layout of a computed tomography (CT) scanner, proving highly effective for treating various oncological diseases. The success of Tomotherapy relies on precise treatment delivery, ensured by the Tomotherapy Quality Assurance (TQA) system. TQA is a comprehensive software that performs pre, during, and post-treatment checks, including equipment, output and energy control, and dosimetric checks. Though complex and requiring specialized knowledge, TQA's clear benefits lie in ensuring high-quality care while optimizing time and personnel resources.

Materials and methods: The checks provided for in this program can be carried out with the equipment supplied by the company together with the Tomotherapy equipment integrated with a few other instruments normally and easily available in a radiotherapy centre. In particular, the necessary equipment consists of: TomoPhantom cylindrical phantom supplied, Rectangular solid water phantom composed of several overlapping layers of different thicknesses supplied with the tomotherapy system, ater phantom equipped with a mobile arm with automatic movement system supplied with the tomotherapy system, Pencil chamber type ionization chamber at least 17 cm long with constant response along the entire length, Software for the acquisition and analysis of transverse, longitudinal and in-depth dose profiles acquired with ionization chambers in solid water phantom or water phantom, Cylindrical ionization chambers of the “minichamber” type (collection volume 0.056 cm^3 .

Results: Measurements made with ionization chamber in a solid water phantom (Cheese- Phantom and Slab-Phantom) have become the baseline values for the reference dose of a standard IMRT plan and for an energy control parameter (PDD20-10). Before starting the treatments, patient-specific checks are routinely carried out on a cylindrical diode array (ArcCheck – Sun Nuclear) and the results obtained on the patients demonstrates excellent agreement after the gamma analysis (3% - 3 mm). Simultaneously with the creation of a baseline for reference dose and PDD (Percentage Depth Dose), the baselines were acquired via direct measurement with the integrated array of detectors into the TQA (Tomo Quality Assurance) software. This method of measurement and processing dosimetric data has made possible obtain an estimation of numerous fundamental parameters of the system.

Conclusion: TQA platform has demonstrated to be reliable in monitoring the main parameters of Tomotherapy. The main advantage is the low time needed to acquire and analyze data. against a Farmer chamber. The Acuros calculation algorithm in Eclipse greatly underestimates the out of field dose and can be used only for a rough estimation in points not so far from the central axis of the beam (less than 20 cm). Ultimately, the Tomotherapy system analyzed was consistent with the specifications provided by the manufacturer and international protocols and has remained so over time.

Dosimetric Evaluation of Prostate Motion using Multimodal Imaging on Extreme Hypo-fractionated SBRT

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Prospective/Objective: Evaluate the dosimetric effect of prostate intrafraction motion on extreme hypo-fractionated SBRT treatments performed in Modena University Hospital, where SBRT-VMAT 6 MV FFF treatments for PCs are delivered using an Elekta VERSA HD accelerator with on-board CBCT X-ray Volumetric Imager (XVI®, Elekta Oncology Systems), and the image guidance of a Clarity Autoscan Ultrasound Based System (Elekta, Stockholm, Sweden) with transperineal probe for prostate movement monitoring and management.

Materials and methods: The data used for the analysis corresponded to 10 prostate acinar adenocarcinoma cases. The prescription was 36.25 Gy total dose in 5 fractions delivered every other day. The information relative to the mean movement of the prostate during each delivered fraction of the treatment for each patient was retrieved through the Clarity Autoscan Ultrasound Based System, to calculate an approximation of the motion-inclusive dose distributions and evaluate the dose difference between the planned and motion-inclusive dose considering the fulfillment and variation of the dose values related to the clinical constraints. Moreover, a tendency of the prostate movement was found and correlated to the dosimetric impact of under coverage of target and overdosage of OARs.

Results: Prostate movement in posterior direction seems to be recurrent during delivery of the treatment. For the target, dose under coverage as large as 4% (124 cGy) respect to the constraint value (D98% > 95%) has been observed in some individual motion-inclusive simulated fractions (16% of the total number). Only rectum and penis bulb showed a worsening in achieving the clinical constraints due to the prostate movement, yet only for a few fractions.

Conclusion: The mean shifts of the prostate during delivery of the radiation treatment don't generate a significant worsening in achievement of the dose constraints in the surrounding organs at risk. For target coverage, a violation of the D98% dose value constraint was found in a little number of fractions, yet over the course of treatment this issue won't be relevant as the displacements large enough to generate an insufficient target coverage are infrequent.

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Evaluation of a new secondary independent dose calculation tool in VMAT treatment planning.

Prospective/Objective: IMRT and VMAT have become the predominant radiotherapy techniques for a variety of treatment sites. The steep dose gradients generated by means of dynamical multileaf collimator motion, gantry rotation speed and dose rate can increase potential errors. Consequently, extensive pre-treatment quality assurance program is needed for the dosimetric verification of the plan, in order to ensure the accuracy and safety of the treatment. The purpose of this work is to perform pre-clinical evaluation of the Delta4 Insight (Scandidos, SWE) as a quality assurance system capable of three-dimensional dose calculations on patients Computed Tomography dataset and a model-based Monte Carlo algorithm comparing it with a reference TPS "Monaco".

Materials and methods: 3 planning situations have been considered: 3D plans in a 30×30×30 cm3 cubic phantoms created by superimposing slabs of varying densities to test the dose calculations within homogeneous structures and inhomogeneities in order to compare PDDs and dose profiles in different depths for both Monaco and Delta4 Insight; VMAT plans in a phantom based on the Task Group 119 and finally, 18 real patient plans in different anatomical sites, to evaluate real clinical situations, using a VMAT technique too. Calculations have been performed for 6 MV and 6 MV FFF photon beams.

Results: For the homogeneous cubic phantom, the mean values of the PDDs confidence limit for 6MV and 6MV FFF forced were (0.50±0.08) and (2.40±0.22), for non-forced (1.19±0.29) and (1.66±0.26), and the mean values of the profiles were (0.84±0.53) and (0.88±0.46). The mean values without forcing the structure (0.79±0.42) 6 MV and (0.75±0.33) 6MV FFF. Cubic phantom with internal low-density the mean values for the PDDs 6MV and 6MV FFF with 5 cm Inhomogeneity were (1.45±0.55) and (1.19±0.19). And for 10 cm (1.75±0.39) and (1.95±0.38). Profiles mean values for 6MV and 6MV FFF with 5 cm of Inhomogeneity were (0.83±0.45) and (0.71±0.33). And with 10 cm (1.02±0.51) and (0.70±0.31). For the cubic phantom with 3 cm internal low- and high-density inhomogeneity the mean values of the x-axis confidence limit for 6 MV and 6 MV FFF were (0.81±0.59) and (0.82±0.47). Regarding to the TG 119 phantom plans, the mean values of the GPR for 6 MV with different criteria were (82.4±5.7) 1%-1mm, (97.4±2.0) 2%-2mm and (99.6±0.3) 3%-3mm. And for 6 MV FFF (85.8±4.4) 1%-1mm, (98.8±1.0) 2%-2mm and (99.9±0.1) 3%-3mm. Finally for the 18 Real patient plans the mean values of the GPR for H&N and different criteria were (79.9±7.3) 1%-1mm, (95.7±2.8) 2%-2mm and (98.5±1.1) 3%-3mm, for Thorax (75.9±10.6) 1%-1mm, (93.9±4.0) 2%-2mm and (97.9±1.6) 3%-3mm, finally, for Pelvis (72.1±3.3) 1%-1mm, (93.8±2.1) 2%-2mm and (97.9±1.0) 3%-3mm.

Conclusion: This study revealed differences in profiles and PDDs, indicating a deviation from the expected shape and calculated dose levels. The comparison made performing the gamma analysis showed no significant discrepancies in both TG 119 and real patient plans, but the DVH comparison showed that DI always delivers higher doses to target and organs at risk, due to the different volume that DI takes into account. These results could suggest to Scandidos some changes in the software before its clinical implementation.

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Quantification and Assessment of Skin Dose in VMAT and Tomotherapy: a Comparative Study using In vivo Dosimeter

Prospective/Objective: This study aimed to evaluate the precision and accuracy of the MOSFET dosimeter in determining skin dose during Volumetric Modulated Arc Therapy (VMAT) and Tomotherapy treatments by comparing them with Gafchromic EBT3 film and the Tereatement Planning System (TPS). The research was conducted at the Instituto Oncologico de Veneto.

Materials and Methods: Thomson & Nielsen, Canada, produced the TN502RD MOSFET detectors. A set of tests was done on the mobile MOSFETs to see how accurate, repeatable, and angle-dependent they were. We were measuring the surface dose in a 6 MV beam on the TrueBeam machine and TomoTherapy. Measurements were performed on a RANDO antropormorphic model simulating head and neck cancer and breast cancer. Treatment plans were generated using the Eclipse treatment planning system for TrueBeam and Raystation for Tomotherapy, adhering to clinical protocols. VMAT plans included two arcs for the head and neck, and for breast cases, two half arcs were employed. For patient-specific quality assurance, portal vision images and arc checks are conducted before taking measurements. This ensures that the positioning and setup align with the treatment plan and verifies the accuracy of the delivery system before actual dose measurements are taken. MOSFETs, along with small 4x4 cm^2 pieces of EBT3 films, were positioned identically on the RANDO phantom to facilitate a comprehensive comparison between them.

Results: The study examined average percentage dose differences in both in-field and out-of-field measurements. When measuring Tomotherapy in-field, MOSFET always shows a higher percentage dose (7.50%) than Gafchromic film. This could be a sign of a systematic bias. The negative percentage difference between MOSFET and TPS in the in-field setting suggests a tendency for TPS to overestimate doses compared to MOSFET (-6.53%). Out-of-field measurements in Tomotherapy show that MOSFET gives more accurate readings than Gafchromic film (4.25%), while TPS significantly overestimates (-3.38%). When we look at TrueBeam, the in-field measurements show that MOSFET readings are consistently higher than Gafchromic readings (13.22%), which could mean that the dose estimates are different. The positive percentage difference between MOSFET and TPS in the in-field setting suggests relatively good agreement between the two measurements (9.78%). However, in out-of-field measurements, MOSFET again shows higher readings than Gafchromic film (6.425%), and TPS exhibits a slight underestimation (1.32%) compared to MOSFET. A study by Rajesh A. Kinhikar [14] and ZHEN-YU QI [13] showed a difference of 20–12%.

Conclusion: After a comprehensive analysis of our data, it is clear that our MOSFET system demonstrates stability and reliability, signifying its robust performance. The consistently accurate measurements obtained through MOSFET play a crucial role in upholding the overall quality and safety of the radiation treatment process. This steadfastness emphasizes the suitability of the device for precise dose verification, further strengthening its integral role in preserving the integrity of radiotherapy treatments.

The use of Hyperthermia to Enhance Radiotherapy Treatments

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Prospective/Objective: Surgery and Radiotherapy are treatment of choice for early stage localized tumor lesions. However, recurrences and/or metastases can occur after incomplete eradication of the primary tumor and lead to acquired radio-resistant tumors, e.g. Hypoxic tumors. Combined radiotherapy and hyperthermia offer great potential for the successful treatment of radio-resistant tumors through thermo-radio-sensitization. The aim of this study was to see the dose escalation effect of hyperthermia on six soft tissue sarcoma patients treated with a preoperative radiotherapy with 25 fraction (2Gy/fr) (for five weeks) and hyperthermia once in a week. In addition we also evaluated local response to hyperthermia and radiotherapy as a preoperative regimen for STS from the post treatment assessment.

Materials and methods: External beam radiotherapy planning was done on a prescription dose of 50Gy in 25fractions using Eclipse v.15.1 TPS. A VMAT technique was used for the six STS patients using 6MV photon beam and evtaluated according to the internal protocol for OARs and limiting the hotspots to the targets. Then the hyperthermia treatment planning was done on Plan2heat software using temperature optimization method (T_{90}, T_{50} and T_{10}) limiting the hotspots to < 45^0C. The Linear Quadratic (LQ) model extended with temperature dependent LQ parameters $\alpha(T,t_{int})(Gy^{-1})$ and $\beta(T, t_{int})(Gy^{-2})$ was used to model the radio-sensitization by hyperthermia. For the LQ parameters of hypoxic volume Oxygen enhancement ratio was used to take in to account that it has a lower sensitivity than the GTV. MIM Maestro® was used to calculate the Equivalent Radiation Dose for the combined treatment and also used to evaluate the treatment outcome by comparing the pre and post K_{trans} maps extracted from Dynamic Contrast Enhanced(DCE) MRI.

Results: A model to quantify the effect of combined radiation therapy and hyperthermia in terms of equivalent dose distributions was presented. Then dose escalation effect of hyperthermia was evaluated by comparing the equivalent dose distribution (EQDRT) for radiotherapy treatment only with the EQDRHT for the combined treatment. From the comparisons it was found that the higher the achieved temperature is the higher its enhancement will be. For the GTV using T10 the enhancement ranges from 4.1Gy (with T10-41.90C) to 6.8Gy (with T10-43.60C) and for the hypoxic volume the enhancement was 5.3Gy to 6.5Gy. For the treatment outcome evaluation hypovascularized volume of the tumor is evaluated with the MIM software as a subvolume of the GTV, for the patient with pleomorphic liposarcoma it has seen an increase in volume (+27%-GTV, +114%-hypoxic, with 40% necrosis) after the treatment because of the histology of the tumor while for the other the GTV and hypoxic volume becomes reduced (-37% , -21%, with 90% necrosis).

Conclusion: Biological modelling provides relevant insight into the relationship between treatment parameters and expected EQD. It has been shown that for a higher enhancement effect temperatures higher than 410C should be applied in order to get a significant amount of equivalent dose from HT. The volumetric maps of Ktrans allowed us to observe important variations between pre- and post-treatment, and therefore the sequence of DCE-MRI was found to be a potentially useful tool in monitoring radio-hyperthermia treatment outcome.

Commissioning of An Elekta VersaHD Linear Accelerator in Pinnacle Treatment Planning System.

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Prospective/Objective: The commissioning of Radiotherapy Treatment Planning System (RTPS) is the most crucial parts of the whole planning process. Indeed, a thorough commissioning is mandatory to ensure an accurate correspondence of the delivered dose to the planned one. The purpose of this thesis was to implement a physical photon beam model for PINNACLE TPS and the electron beam model for RayStation TPS and to create a single physical model able to match the dose output of the three Clinical Elekta Linacs VERSA HD installed at the Radiotherapy Unit of San Bortolo Hospital. Software tests and algorithm validations were performed in order to verify inter-linacs matching of absolute dose and beam flatness for energies of 6FF MV, 6FFF MV, and 10FF MV. The aim was also to define dose characterization procedure for inter-comparison purposes for the three linacs to contribute to a better understanding of the accuracy of single physical model, and to establish a reliable tolerance test report process-based tolerance and action limits of our Elekta VersaHD linear accelerators according to TG-218.

Materials and methods: An Elekta VersaHD (Elekta VersaHD, Stockholm, Sweden) was commissioned, and photon energies of 6FF MV, 6FFF MV, and 10FF MV (profiles, percentage depth doses, and output factor) were acquired for field sizes of 0.6 x 0.6 cm^2 to 40 x 40 cm^2, for wedge fields in various sizes, including 3 x 3 cm2 (without reference detector), 5 x 5 cm^2, 10 x 10 cm^2, 20 x 20 cm^2, and 40 x 30 cm^2. For electron beams the electron cones (applicators of) 6 × 6 cm2, 10 × 10 cm^2, 14 × 14 cm^2, and 20 × 20 cm^2 were used. The data obtained for both electron and photon beams type using a three-dimensional water phantom at a 100 cm SSD, detectors of various types, including Microdiamonds (PTW 60019), Sun nuclear edge detectors, Farmer chambers (TM 30013), Semiflex chambers (TM 31010), pinpoint (PTW 31014), and Advanced Markus (TM-34045), were used, the Sun Nuclear ArcCHECK was used for gamma analysis.

Results: The PDD of 6FF MV was marginally lower than that of 6FFF MV beams at a depth of 10 cm. When compared to open fields, wedge filters considerably reduce machine output while increasing the percentage depth dose. The energy output factor with the flattening filter was higher than that of the flattened beams for field sizes greater than 10 x 10 cm^2, but lower for field sizes less than 10 x 10 cm^2. The pass-rate metrics of 2 mm/2%, 2 mm/3%, and 3 mm/3% with an acceptable threshold of 90% for a Seven VMAT plans simulated using the Unicum model were clinically acceptable for the VersaPOD and VersaHD machines.

Conclusion: The VersaHD linac commissioning data, including depth dose, beam profiles, output factor, and other dosimetric data, w measured, analyzed, and characterized systematically. Photon beam modelling has been done for Pinnacle TPS, whereas electron beam modeling has been done for RayStation.

Setup of a system for online in vivo Dosimetry in VMAT treatments

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Prospective/Objective: To secure the patient treatment quality many tools can be used. In this study, the impact of setup of a system for VMAT treatment was analyzed. The analysis was done on 16 treatment plans using a PTW Verisoft and EPIgray of DosiSoft software. Errors arising during VMAT treatment could cause sever injury to patient due to high radiation dose per single fraction; therefore giving priority for setup of the system we can reduce the risk of errors that could compromise treatment outcome.

Materials and methods: In order to determine the impact of shifts in positioning on a patient-like phantom, we deliberately introduced the following errors. Shift in isocenter of 5 mm and 20 mm in the lateral direction (Plan_L05 and Plan_L2 respectively), a shift of 10 mm and 20 mm in posterior direction (Plan_P1 and Plan_P2 respectively), and 20 mm shift in anterior direction (Plan_A2).

Moreover, in order to examine the sensitivity of the system for the change in size/shape or weight of the patient-like phantom, we introduced a bolus (Plan_B) with thickness 1 cm and area 15 x 15 cm^2 and in order to simulate and evaluate the impact of air bubble within the tissue we introduced a dedicated a 3 cm thick rotation unit chamber plate Farmer 0.3 cm^3 (Plan_Farmer) into the PTW OCTAVIUS 4D phantom

Results: From Plan_L2, Plan_P1, Plan_P2 and Plan_ A2, the expected dose difference (from Pinnacle TPS) were higher compared with DosiSoft. On the other hand, the dose deviation predicted from EPIgray of the DosiSoft for Plan_L2 are lower than the one predicted from the Pinnacle TPS. On the contrary for Plan-Farmer all evaluated structures have a deviation greater than 10%. This shows that EPID based EPIgray of DosiSoft is very sensitive to the change in the density by Farmer Chamber plate which mimics the presence of air bubble within tissues. When examining the gamma index analysis for both 6 MV and 6 MV FFF energies, the gamma analysis via VeriSoft between the Pinnacle TPS and the measured dose maps through PTW729 detector all plans except Plan_Farmer showed a dramatic drop on gamma passing rate relative to Plan_0. Here we can notice that the VeriSoft is not sensitive to air bubble simulated as the Farmer chamber plate, which inserted into the PTW OCTAVIUS phantom.

Conclusion: By combing the EPID based EPIgray of the DosiSoft with the existing PTW VeriSoft gamma analysis technique we can boost the safety of patient and we can offer a comprehensive patient specific quality assurance that can detect errors due to anatomical change, or due to air bubbles between tissues or slight increase on weight of the patient as well as patient positioning errors introduced in the isocenter shift.

Dose Optimization Process for Full-Spine Digital Radiography in the Pediatric Population Using Exposure Index

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Prospective/Objective: the study should cover in multiple beams radiogram the entire vertebral spine in AP and lateral projection. Often, the acquisition should be repeated during long-term evulation. Patients are normally pediatric. The cumulative dose and radiation risk are higher in comparison with other radiographies. The aim was to create a dose optimization process based on a weight of the patient protocol that allows to reduce dose and at the same time keeping a good image quality.

Materials and methods: We analyzed 132 patients: 75 females and 56 males. The ages covered were 3 to 17 years old. Studies were obtained on a Ysio Max Siemens system in the pediatric hospital Regina Margherita of Turin. The equipment created the image stitching multiple beam radiograms. Radiology information were extracted using PACS and the dose tracking system. The exposure index was used for the optimization process; in addition, we needed the weight of the patient and the mAs registered. To study exposure index variations, we analyzed images obtained from a homogeneous and an anthropomorphic phantom. To assess the image quality, four radiologists ranked a group of 20 clinical images obtained pre and optimization and we measured the SNR and CNR using Image J. To simulate organ doses and radiation risk, we used PCXMC 2.0, simulating patients whose ages were 5, 10, and 15 years old and we used a GAF chormic film to obtain beam geometry information for the simulation.

Results: The optimized protocols were classified according to the number of beam radiograms stitched, projection, and weight of the patient. Before the optimization, the exposure index presented high variation between each beam radiogram; after the optimization, this variation was reduced. The DAP mean value was reduced differently according to the protocol and the dispersion of DAP values was reduced more than 70%. Our study showed that the Exposure Index may vary by more than 30% depending on the clinical protocol set in the console. The radiologist's evaluation showed that the new protocols had good image quality. SNR measurements suggest a slightly lower quality of the thoracic vertebras in AP projection. Radiation dose and radiation risk were reduced by even more than 50% in most of the organs according for early ages.

Conclusion: The dose optimization process succeeded in reducing the dose organs and obtaining a good image quality in most of the anatomy components. Optimized protocol turned the Exposure Index and DAP into more predictable variables to be used in future dose optimization programs. We consider that the method of dose optimization presented in this research can be applied to any radiological examination performed with digital equipment. It is important to consider that the exposure index should not be the only indicator into; it is also essential to take into account DAP and the correct radiography technique.

Verification of Ethos CBCT-guided online adaptive radiotherapy for prostate cancer using Raystation hybrid DIR algorithm, ANACONDA

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Prospective/Objective: Radiotherapy plays a crucial role in managing localized prostate cancer, where the planning process involves utilizing a snapshot dataset of the patient's anatomy during simulation. However, anatomical changes can occur between and within fractions, necessitating adaptation strategies. This study aims to comprehensively analyze the dynamics of dose accumulation during the treatment localized of prostate cancer, utilizing both scheduled plans (SPs) (reference treatment plan recalculated on the daily anatomy) and adapted plans (APs) (reference treatment plan reoptimized to match the clinical directive) within the Ethos system, employing the Raystation ANACONDA DIR algorithm.

Materials and methods: Eight patients treated with Ethos oART (60Gy/20 fractions) were retrospectively selected. The initial reference treatment plan was generated based on the planning CT (pCT) using Ethos. Before treatment, cone beam CT (CBCT) images were obtained, and the pCT data was mapped onto the CBCT image, thus creating the synthetic CT (sCT). An artificial intelligence algorithm then identified the influencer organs (prostate, bladder, rectum, and seminal vesicle). Ethos' deformation algorithm utilized these influencer organs to guide the deformation of the CTV and PTV from the pCT to the CBCT image. SPs and APs were subsequently generated on the sCT.

Daily CBCT images, SPs, APs, and reference treatment plans were transferred to Raystation TPS. Rigid image registrations (RIRs) were executed between pCTs and sCTs, followed by the deformable image registrations (DIRs) using the influencer organs as controlling regions of interest (ROIs) for each fraction. The dose corresponding to the DIR was then deformed to the pCT, and a dose accumulation analysis was conducted for both scheduled and adapted plans across all patients. Evaluation metrics included the Dice similarity coefficient (DSC), mean distance to agreement (MDA), and the Jacobian determinant (JD).

Results: Results indicated favorable DIR metrics, with influencer organs mean DSC ranging from 0.89 to 0.98, and the MDA from 0.03 cm to 0.09 cm. JD values for prostate, bladder, rectum, and seminal vesicle ranged from 0.77 to 1.11. notably, AP demonstrated improved PTV coverage compared to SP. For D98% > 95%, 25% of the patients achieved an adapted mean of 94.65%, compared to 12.5% achieving a mean of 88.05% for the SP. For D95% > 95%, AP displayed enhanced PTV coverage, with 100% of the cohort attaining a mean of 97.16%, whereas 25% achieved 92.25% for SP. CTV coverage remained high in both plans, with mean values of 98.03% and 99.13% for SP and AP, respectively.

Although OARs met clinical goals in both plans, AP exhibited increase volumetric dose to OARs. Patient-specific results unveiled target coverage coincidence in four cases, while the remaining four showed a deviation of PTV coverage between Raystation and Ethos delivered dose accumulations, signifying the impact of anatomical changes during adaptation.

Conclusion: Ethos oART emerges as an appealing modality for intact prostate cancer treatment, offering satisfactory CTV and PTV coverage while safeguarding OARs. Potential improvements in PTV coverage could be achieved with enhanced patient preparation and increased clinical staff efficiency.

Acceptance and commissioning of a Philips Incisive CT

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Prospective/Objective: Acceptance testing of a CT is done when a new device has been installed or there was an upgrade to existing equipment. The objective of this study is to evaluate a Philips Incisive CT system recently installed at Desio Hospital, evaluating if the device is as delcared by the vendor, if up to standard with national and international guidelines and establishing benchmark data from acquisitions.

Materials and methods: The Philips Incisive CT system has a 72cm bore and 50 cm field of view detector array used for head, body, cardiac and vascular applications. RaySafe measurement system with two sensors were used: the CT sensor is a 100 mm pencil-ionization chamber which can calculate kV, mA and or mAs from the measured voltage and the survey sensor, which will be used for leakage measurements. Catphan 600 for performance characterization, PMMA head and body phantoms of 160 and 320 mm respectively used for CTDI measurements. Philips Head and Body system performance phantom has a head phantom 200 mm in diameter and the body phantom 300 mm in diameter. Physics layer is for slice thickness and impulse response. Head water layer for measuring noise, CT number and uniformity. The PE and LEXAN/Acrylic cylinders are used for measuring the CT number linearity. The body water layer is used to measure CT number, noise and uniformity. The values to be examined with CT sensor are CTDI in air, weighted CTDI, CTDI reproducibility and linearity vs mAs and CTDI accuracy. With the Philips phantom spatial resolution, noise, mean CT number and uniformity, and slice width were assessed. The survey sensor accounted for the leakage. Finally, tube modulation was evaluated with the use of a combination of head and body phantom.

Results: The values for CTDI in air, weighted CTDI, CTDI reproducibility and linearity vs mAs and CTDI accuracy were all in agreement with the established manufacturer reference values of less than 20%. The declared values on the console for CTDI and geometric efficiency reflected accurately what was measured and calculated by the medical physicist. The current modulation of the x-ray tube illustrates higher variation for the larger collimation. Average radiation dispersion was measured to be 0.1 mGy/h, below the established reference value of 1 mGy/h. The automatic systems check evaluated the mean CT number and uniformity, noise and spatial in which all parameters received a ‘Passed’ status showing the fell within the benchmark ranges stipulated by the International Electrotechnical Commission (IEC).

Conclusion: The Philips Incisive CT passing these examinations suggest that from a theoretical point of view the device is ready for clinical use. That there can be strong levels of diagnostic confidence and that images the device produces will be of minimal noise, which means high levels of spatial resolution allowing the practitioner to be able to better identify structures and pathologies. Resulting in safer and better-quality patient outcomes. The radiologists make the final decision on its efficacy in clinical practice.

Replanning of a proton therapy plan with photons: Analysis of a fast and effective method.

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Prospective/Objective: The aim of this study is to evaluate photon plans created as a backup to the main proton plan in the event of a breakdown of the proton cyclotron for up to 2 weeks. Backup plans are created using the volumetric modulated arc therapy (VMAT) technique for various areas of interest: brain, head-neck, column.

Materials and methods: Nine brain, head and neck (H&N), column VMAT plans for nine patients (3 patients for each case) were created, starting from clinical proton plans. Two tools within RayStation (version 12A) treatment planning system (TPS) were used: Fallback (FB) and autoplanning (AP) by Guided Planning Solution (GPS), which is a Monte Carlo and Collapses Cone-based TPS. Plan quality was evaluated by using dose metrics: V95%, V105%, D95 and limit dose to organs at risk (OAR) from prescription plan. Patient specific quality assurance (QA) was performed for one patient from each group case with gamma analysis.

Results: V95 dose coverage was achieved for half of all plans. Due to the proximity of the tumor to the primary OARs, the minimum dose coverage in V95(%) could not be achieved and a decision was made on the most achievable coverage while sparing most of the OAR for 4 patients. On one of the brain patients an additional optimization was performed, as a test for further improvement of the automatic plan quality. A reduction in dose to the primary OAR was achieved, with a small decrease in dose coverage for both methods. All gamma analysis carried out for patients passed the acceptable treatment limit of 90% with tolerance 3%/3mm. For further verification, tolerance of 2%/2mm was successfully tested; only in one brain case patient the gamma passing rate was lower than the limit.

Conclusion: Both FB and AP methods were effective in order to create a backup plan starting from the clinical proton plan for our sample of nine patients. FB is faster than AP, therefore it is more suitable when time is an issue. AP leads to a higher coverage of the PTV, compared to FB, if the OARs are not near to the target. Additional optimization is recommended in order to improve plan quality for both FB and AP, when OAR are in close proximity to the target. This requires an extra work of about 30 to 40 minutes.

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A practical approach to Stereotactic Radiation Therapy plan verification with matrix detectors

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Prospective/Objective: The aim of this work was to evaluate the impact of dose rate and fields dimension on the Octavius 1500 (OD1500) and Octavius 1600SRS (OD1600) detectors' measurements and to define a calibration procedure for the two matrices, in order to verify SBRT and SRS VMAT plans (6MV FFF and 10MV FFF energies).

Materials and methods: This first part of the work evaluated the response of OD1500 and OD1600 detectors (ODs) to different fields and dose rates for 6 MV, 10 MV and 6 MV FFF, 10 MV FFF energies of an the Elekta™ Versa HD accelerator. Output factors (OF) were compared to the measurements performed during the linac's acceptance test and annual QA verifications, with the dosimeters of reference: ionization chambers (PTW Semiflex 3D, PTW PinPoint, PTW micrioLion) and solide state detector (PTW Microdiamond). The second part of the work was focus on the determination of matrices' calibration factors corrections for SBRT QA plan verifications. The matrices were cross-calibrated ionization chambers PTW Pinpoint and PTW Semiflex 3D, with a 5x5cm2 field at 6MVFFF and 10MVFFF energies. Dose measurements were acquired for small fields varying dose rates to determine the matrix's calibration's correction factors (k_{fs}^{dr}), as a function of field dimension and dose rate. k_{fs}^{dr} values were also compared with the literature. The proper k_{fs}^{dr} was defined for 6 SBRT/SRS plans that were previously analyzed and characterized by their mean segments' dimension and dose rate. The gamma analysis were then performed to compare calculated dose maps and measured dose maps, for each plan (with dose and distance tolerances of 2%, 2mm), before and after the corrections.

Results: OF measured with the OD1500 detector are in good agreement with the reference dosimeters: at field 4×4cm2 and 3×3cm2, deviations were within -0.5% and -1.5%, at field 2×2cm2 the discrepancy is higher, -3.8%. OF measured with the OD1600 in good agreement with the reference dosimeters: at field 4×4cm2 and 3×3cm2, deviations are within 0.3% and 0.8%, at field 2×2cm2 the discrepancy is 2%. Estimated matrix correction factors for the OD1500 are: 1.013±0.003 (for field 3×3cm2) and 1.082±0.003 (for field 2×2cm2) for energy 10MV FFF; 1.014 (field 3×3cm2) and 1.038 (field 2×2cm2) for energy 6MV FFF. These results are in good agreement with the literature; the correction factors for the field 2×2cm2. Matrix correction factors for OD1600 are 1.0 (5×5cm2), 0.97 (3×3cm2) and 0.95 – 0.93 (2×2cm2) for energy 10MV FFF depends on dose rate, 1.0 (5×5cm2), 0.99 (3×3cm2) and 0.98 (2×2cm2) for energy 6MV FFF at maximum dose rate.

Conclusion: Two matrix detectors with OCTAVIUS 2D were analyzed to perform routine QA measurements for treatments SRS/SBRT plans. Our practical approach to correct the matrices' dependence on field size and dose rate give good results in terms of gamma analysis for the SBRT/SRS plans evaluated, but further verifications should be performed to confirm our correction factors estimations.

Dosimetric optimization and evaluation of hepatocellular carcinoma treatment effect prediction in Y-90 transarterial radioembolization

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Prospective/Objective: This study aimed to optimize and standardize the pre- and post- dosimetry protocols for ^{90}Y TARE at ASST Papa Giovanni XXIII Hospital (Bergamo, Italy) and assess the predictive value of voxel dosimetry for treatment outcomes, including radiological response, adverse events and patient overall survival in HCC patients.

Materials and methods: In this retrospective study 133 HCC patients treated with ^{90}Y microspheres from 2013 to 2021 were analysed. Of those 95 were treated with resin microspheres, 38 with glass microspheres. The pre- and post-dosimetry protocols were optimized based on EANM guidelines, utilizing the Planet Dose software. Pre-dosimetry was done for all the patients and the calculated doses were used for statistical analysis. Post-dosimetry was performed for patients treated after installation of the PET/CT system in 2019. Association between mean dose delivered to the lesion and complete radiological response (CR) was assessed by Wilcoxon-Mann-Whitney test, when the dose was considered as a continuous variable, and by chi-square test when the dose was dichotomized using the best cutoff identified by ROC curve. Univariate and multivariable Logistic Regression models were fitted to identify predictors of CR. Cox Proportional-Hazard Regression models were fitted to identify predictors of death. A comparison of doses calculated during pre- and post-dosimetry was performed before and after the optimisation of PET/CT acquisition protocol.

Results: The optimal reconstruction for pre-treatment dosimetry with ^{99m}Tc-MAA with Siemens 'Symbia' SPECT/CT was determined as Flash 3D, 8 subsets, 8 iterations, and no filtering. For resin microspheres from the ROC curve plotted for mean dose delivered to the lesion predicting CR, a cutoff dose was found to be 233.2 Gy (AUC = 0.6191). A significantly higher proportion of CR was found in the patients who received a dose ≥ 233.2 Gy (49.1% of CR with higher doses vs. 23.8% of CR with lower doses, p=0.012), as well as a reduction of risk of death by 42% (HR=0.58, 95% CI 0.34-1.01, p=0.054). The number of patients with complete radiological response treated with glass microspheres was too low to implement a statistical model. No lung toxicity was observed for any of the patients involved in this study. No correlation between the dose delivered to the normal liver and adverse events was found during the statistical analysis. Comparison of pre- and post-dosimetry was performed for 34 patients before the optimisation of PET/CT protocol. In 8 patients mean lesion dose discrepancies of >40% were found. After the optimisation all the lesion doses were within 40% when the pre- and post-dosimetry was compared.

Conclusion: Dose to the lesion is a significant predictor of CR for resin microspheres, the mean dose delivered to the lesion should be at least 233.2 Gy. In patients receiving at least this dose, a reduction of risk of death was observed. The absence of lung toxicity and the lack of correlation between normal liver absorbed dose and adverse events suggests potential under-treatment, advocating for increased delivered doses in future interventions.

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Comprehensive Assessment of Breast Cancer Treatment: Monaco TPS IMRT/VMAT Templates and Positioning using XVI/ $Catalyst^{TM}$

Prospective/Objective: The first part of the thesis focuses into the development and optimization of IMRT and VMAT templates on Monaco TPS for breast cancer treatment. The second objective involves a comprehensive analysis of positioning shifts in breast cancer treatments, specifically comparing patients treated using XVI+$Catalyst^{TM}$ positioning to those treated using XVI positioning alone. Additionally, a subgroup analysis compares XVI versus $Catalyst^{TM}$ shifts. The study aims to evaluate the efficacy and equivalence of these positioning approaches.

Materials and methods: The methodology begins with the transfer of patient data, including RT Plan, Prescription, RT Structure, RT Dose and DICOM Images from Pinnacle TPS to Monaco TPS for template creation. The testing methodology for template assessment involves a direct comparision of Monaco created templates with established reference treatment plans, allowing for an in depth assessment of dosimetric parameters and plan quality. Additionally, prior to the template and reference plan comparison, an in-depth analysis of the coherence and reliability of Dose-Volume Histogram (DVH) data generated by both Monaco and Pinnacle TPS was conducted. Independent Samples T-Tests were emplyed for DVH data analysis. The second part of the thesis is a comprehensive analysis of positioning shifts in breast cancer treatments from August to Novemebr 2023. It compares a group of patients of XVI+ $Catalyst^{TM}$ positioning and a group of XVI positioning alone. The study involved 45 patients, and the total valid sample size (N) across all patients was 260 (N: 115 XVI+CAT and N: 145 XVI Alone). The study used Independent samples T-Test to find the statistical differences in lateral (LAT), longitudinal (LON) and vertical (VER) positioning components. Futher analysis were on XVI vs $Catalyst^{TM}$ shifts on a group of 15 patients, with a (N) sample size of 96 data points. Paired sample T- Test was used on this case.

Results:. Using Independent samples T-Test for 48Gy, 40.05Gy and 26Gy protocols, the study found p-values of p=0.992602, p=0.939864 and p=0.984541 indicating the equivalence of Monaco and Pinnacle TPS in DVH calculations. Moreover, following comparisions of Monaco- created templates with Pinnacle reference plans, using Independent Samples T-Tests for 48Gy (p=0.995776), 40.05Gy (p=0.99082564) and 26Gy (p=0.991866) demostrated large p values, suggesting the equivalence of Monaco templates and Pinnacle in meeting the specified constraints for breast cancer protocols. In the positioning analysis of XVI+$Catalyst^{TM}$ vs XVI alone, no statistically significant differences are observed in LAT(p=0.926) and LON(p=0.631) components. However, the vertical (VER) positioning results reveal a significant difference (p-value:0.030). For analysis of XVI vs $Catalyst^{TM}$ shifts, a significant difference is in longitudinal shifts (p-value: 0.007). Lateral (p-value: 0.450) and vertical shifts (p-value: 0.134) demostrate comparability.

Conclusion: Statistical analysis across breast cancer protocols indicates high p-values, confirming equivqlence between Monaco and Pinnacle plans. Monaco templates are deemed safe for treatment planning. XVI+$Catalyst^{TM}$ vs XVI alone reveals comparable lateral and longitudinal positioning but a significant difference in vertical positioning. XVI vs $Catalyst^{TM}$ suggest attention in replacing XVI with $Catalyst^{TM}$ especially in scenarios requiring precise longitudinal positioning.

Minimax robust optimization of VMAT in stage III lung cancer patients: a dosimetric comparison with the PTV-based approach

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Prospective/Objective: to study the performances of the Minimax Robust Optimization (MRO) approach for Volumetric Modulated Arc Therapy (VMAT) planning compared to the standard (PTV-Based) strategy to treat stage III lung cancer patients. The research aims to quantify the advantages of MRO in lung cancer settings by robust evaluation of standard plan quality metrics like DVH points dose conformity and homogeneity indexes.

Materials and methods: Standard and robust VMAT plans were generated by the TPS Raystation v12b, selecting a cohort of ten patients from a Stage III-NSCLC publicly available archive. For both plans, a 6MV photon beam from a clinically commissioned Linac Varian Trilogy equipped with a Millennium MLC system was employed. Treatments were planned using a synthetic CT obtained from an average of 10 phases of a 4D-CT scan; the same 4D sequence was used to generate the ITV for the standard plan arm. Systematic and random positioning errors from baseline and motion-induced shifts were evaluated on 14 patients, coming from the same archive, with 5 consecutive verification 4D-CBCT scans. A single population-based margin yielding ±5mm, ±8mm, and ±5mm in the LL, SI, and AP directions was derived and used for PTV generation in the standard arm and to set the robust optimization parameters in the robust one. The dose distributions were analysed using the TPS robust evaluation tool, comparing the values obtained for all the selected dose metrics in all the simulated geometrical uncertainty scenarios. Isotropic shifts of ±3, ±5, and ±8mm magnitude were applied to evaluate the robustness of the two approaches against the geometrical uncertainties. Descriptive statistics and a non-parametric Wilcoxon sign test were carried out to assess if the differences were statistically significant.

Results: No significant differences were found in terms of CTV coverage for uncertainties up to 5 mm. A statistically significant difference was found ($p= 0.001$) in the worst-case scenarios, slightly exceeding the robustness parameters. In this case, the robust plans underperformed the standard ones, highlighting their sensitivity to errors exceeding the limits set in robust optimization. In terms of dose conformality, robust plans significantly outperformed the standard ones without affecting dose homogeneity. The dose of OARs was systematically lower in the robust arm, with clinically and statistically significant differences ($p< 0.0001$). To cite the closest OAR to CTVs, the reduction of mean and maximum dose to the oesophagus was respectively 1.41±1.55 Gy and 5.79±7.86 Gy. Finally, robust plans required less modulation as a result of a significant reduction in the Monitor Unit number ($p = 0.012$).

Conclusion: MRO led to improved target coverage and dose reduction to OARs with a lower complexity profile without compromising the treatment safety with potential clinical benefits in advanced lung cancer treatments.

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Performance assessment of different reconstruction algorithms, performed with AAPM Task Group 233 CT task-based image quality metrics.

Prospective/Objective: In the past few years, Computed Tomography (CT) vendors introduced Artificial Intelligence Deep Learning Reconstruction (AI DLR) algorithm to overcome the limitation of Iterative Reconstruction (IR) algorithm. The purpose of this work is to provide a qualitative characterization of IR and AI DLR algorithms of different commercial vendors, focusing on image quality protocol optimization based on the qualitative metrics suggested by AAPM TG 233 protocol.

Materials and methods: A 128 slices GE Revolution System and 320 slices Canon Aquilion One Prism were used in this study to assess image quality of advanced reconstruction algorithms. Acquisition were carried out using Catphan phantom model 600. A clinical head protocol was selected on GE Revolution CT. Different acquisitions were performed with three slice thickness (1.25, 2.5 and 5 mm) and CTDIvol values equal to 18.82, 18.88 and 20.77 mGy respectively. Images were reconstructed using one level of iterative ASIR (ASIR50) and AI DLIR with three different strengths (LOW, MEDIUM and HIGH).

On Canon Aquilion One Prism, both head and body protocols were used. Data were acquired with CTDIvol values equal to 52.7 mGy for head and respectively 3.2 and 6.3 mGy for body, with three slice thickness (1, 3, 5 mm). Images were reconstructed using AIDR 3D as Adaptive Iterative Dose Reduction algorithm and Advanced intelligent Clear-IQ Engine (AiCE) based on deep learning reconstruction technique. Task-based Transfer Function (TTF) and Noise Power Spectrum (NPS) were computed. Detectability Index (d') was calculated using the nonprewhitening matched with eye filter (NPWE) model observer.

Results: Generally, for each slice thickness the ASIR-50 shows a slightly superior or comparable values of TTF50% and TTF10% for all the Catphan inserts evaluated, respect to AI DLIR and its different strengths. Starting from ASIR50 to DLIR of different levels, a substantial reduction in noise magnitude is confirmed for all the slice thickness. Considering the peak frequency, an evident shift towards lower frequencies have been found only for slice thickness of 1.25 mm and 2.5 mm. Higher detectability index was obtained for AI DLIR and the increment is more evident for high contrast inserts; it also increases varying the strength of the reconstruction algorithm. In Canon CT, using head protocol, AiCE_brain shows a shape reduction of NPS compare to AIDR 3D and AICE_Innear Ear. TTF was higher for AiCE_Inner Ear followed by AIDR 3D and AiCE_brain while an opposite result was found for detectability index. For body protocol, TTF50% and TTF10% were greater with AiCE than AIDR 3D at high contrast insert with low and high radiation dose, while a comparable values were found for low contrast inserts except for acrylic and polystyrene. The NPS was lower for DLR than IR. Higher values of DI were obtained with AiCE than with AIDR 3D at low and high radiation dose and it followed the increment of the contrast insert levels.

Conclusion. The results in this study confirm that both AI deep learning reconstruction algorithms reduce the noise magnitude and improve noise texture and detectability index. Both DLIR and AiCE have a greater impact than IR on the metric results obtained.

Brachytherapy Gynecological Cancer: Equivalent Dose Calculation in Treatment Planning System

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Prospective/Objective: The aims of the thesis is evaluate the feasibility of the treatment planning system in calculating EQD2 total doses to organs at risk (OAR) and target in combined external radiotherapy and brachytherapy treatments of cervical gynecologic cancers.

Materials and methods: Thirty cervical cancer patients treated with external beam Radiation Therapy (EBRT) combined with Brachytherapy (BRT) were reviewed. The simulation CT images of EBRT and four images (CT or MRI) BRT were imported into TPS Raystation (RaySearch Laboratories, Stockholm, Sweden) to perform dose summation based on deformed images (DIR). The total doses to organ at Risk (OARs: bladder, rectum, sigmoid, bowel) and targets (HR-CTV) obtained by adding the equivalent doses in 2 Gy fraction (EQD2) from the EBRT and BRT plans were used for quantitative comparison between the three methods (TPS, Preadsheet of excel and TPS Prospective).

Results: A statistical analysis was carried out to compare the values obtained for the doses of interest using the TPS Raystation module, the values obtained for the doses of interest using the method commonly used in clinical practice (Spreadsheet of Excel) and Prospective. In combined EBRT and BRT, the mean EQD2 sum dose of bladder D2cc calculated by TPS, Spreadsheet and TPS Prospective (TPSprosp) method was (91.7 ± 14.3) Gy, (91.9 ± 9.8) Gy and (93.5 ± 16.0) Gy, respectively. The mean EQD2 sum dose of rectal D2cc calculated by TPS, Spreadsheet and TPSprosp method was (76.1 ± 15.3) Gy, (76.0 ± 11.7) Gy and (80.7 ± 17.3) Gy, respectively. For the target HR-CTV D90 calculated by TPS, Spreadsheet, and TPSprosp method was (88.1 ± 8.9) Gy, (89.13 ± 4.9) Gy and (88.8 ± 6.0) Gy, respectively. End then for HR-CTV D98 for the three method was (76.4 ± 7.9) Gy TPS, (77.5 ± 5.4) Gy Spreadsheet and (74.2 ± 15.1) Gy for TPSprosp method. In this study, all of the p-value was above to 0.05 is it no significant difference between the three method.

Conclusion: The results show that all the values for each method are in line with the dose recommended by the EMBRACE protocol. Comparisons of EQD2 dose values between TPS Raystation to spreadsheet, and TPS Raystation to Prospective do not differ greatly, and are almost similar. The values obtained by these three methods did not show any significant statistical differences. Which allows us to conclude that the module introduced by TPS Raystation could be useful in clinical practice.

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Comparing accuracy of SPICE-CT and CTQA_cp with IQWorks software in Catphan600 image analysis for X-ray computed tomography quality assessment

Prospective/Objective: The significance of software tools in evaluating CT image qaulity, during quality control assessments of CT scanners, is indisputable. Despite the longstanding use of IQWorks at Circolo Hospital Department of Medical Physics, recent compatibility issues have surfaced. This study aimed at investigating altanative freely available software; SPICE-CT and CTQA_cp, and evaluate their accuracy in comparison with IQWorks for the analysis of Catphan600 phantom images. The goal was to offer insights into the usefulness of these alternatives, adressing accuracy concerns and ensuring a consistent and reliable CT image quality analysis.

Materials and methods: Catphan600 images obtained from various CT scanners between January 2022 and June 2023 were utilized. Central images from three Catphan600 modules: CTP404 for evaluating slice thickness, geometry, and CT-number; CTP591 for modulation transfer assessment; and CTP486 for examining uniformity and noise were selected. Axial images acquired from Toshiba Aquilion Prime SP, Toshiba Astelion, GE Medical Systems Evolution EVO, and Philips Brilliance 16 were included in the study. For spiral image analysis, images acquired from Philips Iqon-Spectral CT, Philips Brilliance 16, Toshiba Aquilion Prime SP, Toshiba Astelion, GE Medical Systems Evolution EVO, and Siemens Sensation 64 were utilized. Selected images were analyzed using each software tool. The differences in mean and standard deviation between each software and IQWorks were computed and compared to tolerance levels. The differences between each software and IQWorks were tested using Wilcoxon Signed-rank paired data test.

Results: Comparing SPICE-CT with IQWorks in axial images showed no significant differences in slice thickness (P = 0.655), geometry (p = 0.294), uniformity (p = 0.721), noise (p = 0.915), average CT-number (0.12±3.41) HU (p = 1.000) with no discripancies for individual insert materials, except for Acrylic. Comparing CTQA_cp with IQWorks in axial images revealed no significant differences in slice thickness (p = 0.295), geometry (p = 0.390), uniformity (p = 0.926), noise (p = 0.275), average CT-number (0.65±3.45) HU (p = 0.880) with no significant discrepancies for individula insert materials except for Acrylic. In spiral images, no significant differences were observed between SPICE-CT and IQWorks in slice thickness (p = 0.320), geometry (p = 0.642), uniformity (p = 0.785), noise (p = 0.323), average CT-number (0.58±2.73) HU (p = 0.336) with no significant differences for individual insert materials except Delrin. Generally, MTFs exhibited significant differences ($p < 0.001$) in all cases. While SPICE-CT and CTQA_cp adhered to acceptable tolerances for most parameters, they fell short of meeting the tolerance levels for some MTFs in axial images. SPICE-CT and CTQA_cp were in agreement with IQWorks and measured most parameters within acceptable tolerance levels. However, CTQA_cp did not perform analysis for spiral images.

Conclusion: SPICE-CT and CTQA_cp were consistent with IQWorks and calculated almost all considered image quality parameters to within acceptable tolerances. However, CTQA_cp confined its analysis to axial images. Consequently, SPICE-CT emerged as a viable alternative to IQWorks for axial and spiral Catphan600 image analysis.

Dose estimation to cardiac implanted electronic device in low voltage intraoperative radiotherapy

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Objective: Intraoperative radiotherapy is a specific technique for treating breast cancer that offers several benefits. One crucial aspect of IORT is in vivo dosimetry, which measures the dose at varying distances. Can be also used to estimate the dose to cardiac implanted electronic devices and in this study we aim to estimate the safe distance for CIED. To achieve this, we need to calibrate a type of dosimeter among available dosimeters, thermoluminescence has been used to detect low dose levels. We used a low-voltage machine in our study for the delivery of radiation and a comparison of dose in patients with a water phantom to ensure an accurate estimation of this distance.

Materials & Methods: The low voltage machine is a small machine with a kV x-ray source designed specifically for IORT applications. We used this clinical machine to cross-calibrate TLD dosimeters in the clinical energy spectrum and in dose range of 0-4 Gy. During the IORT of breasts, we utilized this calibrated TLD to measure the dose at varied distances. We placed one package of TLD wrapped in a sterile envelope on the patient's skin after breast-conserving surgery to collect the dose at several distances. The data obtained from actual patients via TLD were compared thoroughly with the data collected in a water phantom using an ionization chamber and TLD.

Results: We cross-calibrated TLDs and determined that they are linear and more sensitive in the low dose range of 0.1-1.5Gy, but need a correction at doses above 1.5Gy. Using this cross-calibration, we measured skin doses during IORT treatment and estimated the dose to pacemakers. Preliminary cross-calibration showed a linear response in the relevant dose range. In vivo measurements using TLD indicated that the technique is completely safe for CIED. The dose at the location more than a certain distance where CIEDs are typically placed in patients was found to be below the threshold of 2Gy.

Conclusion: Clinical evidence was utilized to successfully complete the task. To summarize, the use of TLD in IVD to collect dose data is a viable procedure. The dose and the distance to the CIED were estimated but needed more patients for more accuracy. TLD can be employed for future measurements to well estimate the dose and distance to the CIED.

Commissioning of Elekta Versa HD WFF photon beams and clinical validation into the pinnacle treatment planning System.

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Prospective/Objective: Radiation therapy is a complex process which involves many steps prior to the clinical use of the linear accelerator, each of which requires complete and through commissioning and quality assurance in order to ensure accurate delivery of the prescribed radiation dose to the target. A crucial role in the radiotherapy treatment procedure is played by the Treatment planning system (TPS) because it provides the means to plan individualized dose distributions to the target volume and organs at risk sparing. The purpose of this study is the Commissioning of the Elekta Versa HD linac newly installed in the Radiotherapy Department, the beam fitting and the dosimetric clinical validation of the Philips Pinnacle 3D dose calculation algorithm for external photon beams with flattening filter (WFF).

Materials and methods: An Elekta Versa HD linear accelerator was installed by Elekta company in the radiotherapy department. Acceptance testing was performed by the Elekta specialist together with the medical physicists of the department to verify that the machine performance meets the requested specifications. Following acceptance testing was the beam data collection for commissioning, which was performed for field size ranging from 1cm x1cm to 40 cm x 40 cm by using a single device, the microdiamond synthetic detector, because of its suitable physical characteristics. Beam data were collected with the microdiamond detector in parallel configuration in the PTW MP3 water phantom, which permits to scan the detector in three orthogonal directions in the radiation field. All the measurements were in terms of relative dose, normalized to the point of maximum dose along the beam's central axis for the depth dose curves and normalized to the central axis dose for the dose profiles. For relative field measurements a reference detector (PTW semi-flex chamber) was used in order to obtain a reference signal. Pinnacle Philips TPS was used to perform the beam fitting modelling for the dose computation and also to validate the dose output of the machine for clinical use, by employing various verification methods such as tests in homogeneous phantom and patient specific QA (PSQA). Different statistical tools such Distance To Agreement (DTA), maximum percentage difference and standard deviations, were used to evaluate the discrepancies between measured and computed doses.

Results: All the acceptance tests performed after the Linac installation are within the specified tolerances. Regarding the TPS beam modelling, measured depth dose curves and profiles are in strong agreement with TPS calculations within 2% Dose Difference (DD) in low gradient regions and 2 mm DTA criteria in high gradient regions. Beam specific calculation checks in homogenous media are in strong agreement with the IAEA recommended tolerances. PSQA checks for conformal treatments on different anatomical sites gave optimal results confirming that the dose planned in realistic situations relating to the real treatment of patients corresponds to the one actually delivered.

Conclusion: The Elekta Versa HD linac and the Pinnacle Philips TPS were successfully commissioned for external photon beams with flattening filter and are ready for clinical use.

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Feasibility study of robustly optimized intensity modulated plans with photon and proton beams in head and neck cancer.

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Purpose: This study investigates the feasibility and potential of Multi Field Optimization (MFO) proton plans, Robustly Optimized Intensity Modulated Photon Therapy (RB IMXT) and Planning Target Volume (PTV) based IMXT. The study aims to compare the plan quality and evaluate the robustness.

Methodology: MFO proton plans, RB IMXT and PTV based IMXT plans were created for 3 oropharynx and 2 nasopharynx cancer patients. Plans were evaluated using dose statistics, homogeneity index, conformity number, integral dose and scoring method. Robustness of treatment plans were assessed by introducing residual uncertainties of ±3 mm along the three translational axes. In protons, an additional range uncertainty of ±3.5% was introduced. Robustness of the plans was assessed according to worst scenarios. Statistical analysis includes paired-sample student's t-test and linear regression.

Results: Averaged scores “score is the sum of assigned score for each clinical goal that is achieved” for MFO IMPT was 23%, 13% higher than PTV based IMXT and RB IMXT plan respectively ($P<0.05$). In MFO proton plan, dose to Organ At Risk (OAR) was reduced by 4% to 49% ($P<0.05$) of their dose constraints, whereas for RB IMXT and PTV based IMXT, dose constraints could not be reached in parotids, oral cavity, and submandibular glands. The mean dose variation in Clinical Target Volume (CTV)s among planning techniques for D98% was less than 1.7 % of prescribed dose. The percentage of scenarios in which the clinical goals were achieved was higher for proton plans. Strong correlation was found between the worst scenario dose with nominal ($R^2 > 0.97$) and averaged scenario dose ($R^2 > 0.99$) for CTVs in all plans.

Conclusion: CTV to PTV margins are still used in photon planning. However, for comparable robustness of the plans and CTVs coverage, robustly optimized photon plans could be alternative to PTV based plans that improves conformity and in consequence reduces dose to OARs. MFO proton plans are most effective in decreasing OARs doses and enhancing target conformity keeping the reliability of the plan in terms of its robustness and coverage. It reduce integral dose to healthy tissue that decrease toxicities to patients.

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Commissioning of a stereotactic radiosurgery (SRS) oriented treatment planning system (TPS)

Prospective/Objective: The purpose of this thesis is to commission and validate the Monte Carlo and Pencil Beam algorithms of a Brainlab Elements Treatment Planning System (TPS) for stereotactic radiosurgery (SRS) treatments delivered with a 6 MV flattening-filter free (FFF) beam of a Varian TrueBeam STx LINAC. Comparisons with other two clinically commissioned algorithms, AAA, and Acuros XB by Varian Eclipse, are also performed.

Materials and methods: As part of our commissioning and, quality assurance process, we tested different dose calculation algorithms PB with full beam data (Full PB), both Pencil Beam and Monte Carlo with reference beam data (RBM PB/RBM MC). We compared these algorithms with Acuros XB and AAA algorithms by Varian Eclipse, performing analysis to verify accuracy for SRS photon dose calculation. Validating beam and MLC models, we conducted measurements for depth dose curves, profiles, output factors, and Jaws Leakage. Parameters like offset, gain, leaf tip width, and transmission were determined for MLC. Small field profiles were verified using Gafchromic EBT3 Films, agreeing with water phantom measurements using the microDiamond detector with gamma analysis with DTA 2%/1mm. Clinical SRS plans were calculated with various algorithms at a 1 mm dose grid size and validated with SunNuclear EasyCube Phantom measurements for treatment verification.

Results: The 6 MV FFF beam characteristics aligned well with the literature. Validation confirmed our beam and MLC models for SRS treatments. Point dose measurements for larger field sizes (1x1 cm^2) had excellent agreement (1% ± 0.5%) between the measured dose, pencil beam algorithm, and Monte Carlo algorithm. For smaller rectangular fields, Monte Carlo showed better accuracy and robustness (1% dose difference) due to its precise handling of heterogeneous materials. Acuros XB demonstrated similar accuracy to MC regarding differences from the measured dose.

Conclusion: The SRS EasyCube Phantom measurement agrees dosimetrically with the plans calculated by the Pencil Beam algorithm Full PB and both reference beam model Pencil Beam and Monte Carlo (RBM PB/RBM MC) by Brainlab, as well as the AAA, and Acuros XB dose calculation algorithm by Varian. Point dose calculation for small field dosimetry and differences using SRS EasyCube Phantom both showed that the Monte Carlo algorithm is more robust and is superior in regions of heterogeneous materials. The technical information and dosimetric data provided in this thesis will be a useful reference for other clinics/institutions that will commission the same machine energy in the BrainLab TPS.

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Comparison between two different devices for pre-treatment QA: Arc-check and EPID

Prospective/Objective: One of the most essential tasks of the medical physics workload is to ensure patient-specific quality assurance(PSQA). However, PSQA can be a time-consuming task. International regulations(such as the European Union 2013/59/EURATOM) still recommends it, especially for complex VMAT radiotherapy treatments. To achieve optimal quality assurance on patient plans while saving time, more efficient pre-treatment PSQA methods such as EPID-based measurements are preferred. However, the AAPM TG 218 discourages it because “using EPID to obtain an integrated image for VMAT is considered PC”(Perpendicular Composite). Recently, the AAPM TG 307 reported that few studies compare traditional methods of pre-treatment PSQA(based on ionization chambers or diode arrays) with EPID measurements. Furthermore, to the best of our knowledge, none of them reports results on the Sun-Nuclear Sun-Check Patient Software. This study aims to compare PSQA obtained with the Sun-Nuclear Sun-Check Patient Software against as well-established TC(True Composite) method for pre-treatment QA, such as the Sun-Nuclear Arc-check diode array. The primary objective is to investigate the possibility of replacing traditional pre-treatment PSQA methods with EPID measurements while maintaining the same level of quality assurance.

Materials and methods: During the study, thirty VMAT plans were subjected to repeated measurement using Arc-check in a composite way and with EPID per field. For each arc, an integrated EPID image was registered. It is worth noting that all of the VMAT plans were characterized by two or three arcs. Before every measurement session, linac output was carefully measured and found to be within 0.5% of the reference value. The process of pre-treatment verification of treatment plans is crucial in ensuring the accuracy and safety of radiation therapy. In this study, pre-treatment EPID images were acquired without couch and/or phantoms, and were processed using the Per-Fraction module of the Sun-Check Patient Software. The images were converted into planar dose in water slab at the EPID level and compared with calculated dose maps obtained by the embedded Sun-Nuclear Dose-Check algorithm. Moreover, Arc-check measurements were performed in absolute dose to water after calibrating the instrument, and were compared with the TPS calculations that utilized the Varian Acuros XB algorithm in dose-to-water. The Gamma Passing Rates(GPR) for both the comparisons in absolute doses were registered with different dose-DTA criteria, including 3%2mm, 3%1mm, 2%2mm, 2%1mm, 1%2mm and 1%1mm; all global and with threshold at 10%. The study also analyzed GPR distributions for each approach, and computed the main statistic descriptors such as median, inter-quartile range, maximum and minimum. Additionally, the correlation between each GPR distribution obtained with different detectors was also computed. For the EPID measurements, the per plan GPRs, which is the average of GPR values obtained for each plan arc, were considered. Finally, the study also calculated the action limits suggested by the AAPM TG 218 for each considered dose-DTA criterium. These findings provide valuable insights into the accuracy and reliability of pre-treatment verification methods in radiation therapy, which can ultimately improve patient safety and outcomes.

Results: The report provides descriptive statistics, including the median, inter-quartile range, maximum and minimum values, of the recorded GPRs(Gamma Passing Rate) in a table format. Additionally, the action limits were calculated based on the AAPM TG 218 recommendations. For the EPID(Electronic Portal Imaging Device) measurements, the average GPR values obtained for each plan

arc were reported. The data indicates a general overlap between all the reported GPR distributions, and no further statistical analyses were conducted to compare the groups. Pearson correlation coefficients were calculated for each combination of GPRs distributions with Arc-check and EPID. The coefficients ranged from -0.23 to 0.83, representing the relationship between the 1%1mm criterion for Arc-check and 1%2mm criterion for Per-Fraction Fraction0, and between the 3%2mm criterion for Arc-check and the 3%1mm criterion for Per-Fraction Fraction0. These results provide insight into the correlation between the two measurement methods and can be used to guide further analysis and interpretation of the data.

Conclusion: Based on our evaluation of the EPID pre-treatment PSQA system Sun-Check Per-Fraction and Arc-check, utilizing a sample of thirty VMAT plans, we have determined that there are no significant differences in GPRs distributions across various dose-DTA criteria. This indicates that the EPID pre-treatment dosimetry system could potentially be utilized as a less time-consuming substitute for traditional TC pre-treatment PSQA methods like Arc-check. However, it should be noted that further data obtained from multicentric contests would be necessary to validate this conclusion. Overall, our findings provide valuable insights into the effectiveness of the Sun-Check Per-Fraction system and its potential to improve the pre-treatment PSQA process for VMAT plans.

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A data driven method for quality control of head and neck treatment planning

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Prospective/Objective: The Head and Neck (HN) radiotherapy treatment requires complex planning, and the quality may vary greatly if the plans are manually generated. In fact, plan quality mainly depends on the planner's skills and experience, as well as the time available for optimization. Additionally, when the plans are calculated, there is a lack of consideration for geometric variability between patients. The overlap volume histogram (OVH) serves as an anatomical metric that acts as a tool to link dosimetric and geometric parameters between an organ at risk (OAR) and target volume when predicting expected dose-volumes in knowledge-based planning (KBP). This work investigates the OVH and dose-volume histogram (DVH) correlation as a quality control method for HN cases, in view of automatic planning optimization.

Materials and methods: The OVH curves were generated retrospectively for 19 patients for both left and right parotids using Oncentra V4.5 planning system. The quality control process is established using two distinct methods. The first method involves the expected mathematical relation between the OVH and the DVH for each parotid, to determine if a lower dose could have been achieved. The second method utilizes statistical analysis to establish further correlation between the dosimetric data and the geometric complexity of the parotids and PTVs, incorporating multiple key DVH and OVH metrics.

Results: The expected mathematical relation between OVH and DVH reveals that 13 of our 19 cases can benefit from a possible dose reduction. Out of these 13 patients, 5 of them may need optimization only on the right parotid, 2 patients need optimization only on the left parotid and 6 of them need optimization for both left and right parotids simultaneously. The correlation analysis suggests that the patients' data can be divided into two sets. The first set where dose reduction is difficult due to PTV-parotid proximity, these are high complexity plans. The second set, where the parotids are more far from the target, are plans of lower complexity, and dose reduction could be possible.

Conclusion: The OVH method proved to be an effective quality control tool that can be used to improve volumetric modulated arc therapy (VMAT) planning optimization and reduce user inter-variability.

Robustness of lexicographic optimization based planning for cervical cancer according to different type of organ segmentation.

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Prospective/Objective: In this study, according to literature auto-contouring is generally assessed by comparing with manual contouring, however the effect of the auto-contouring, manual contouring and auto-manual contouring is not known. The purpose of this study is to evaluate the robustness of auto-planning by creating a wish-list and using the same dosimetric constraints on the three types of contouring methods on the organ at risk.

Materials and methods: This study included a cohort of 10 cervical cancer patients treated with volumetric modulated arch therapy (VMAT) technique the prescription dose was of 50Gy in 25 fractions. Before the conduct of this research all the patient related information was anonymized deeply. A computed tomography simulation with 3mm slice thickness was used to acquire images for all the patients. The structure sets that were contoured by three different contouring type that is auto-contouring, auto-manual contouring and manual contouring. The auto-segmented contours were retrieved from the deep learning tool and were manually corrected by ROs where necessary. These contoured structure sets were then used in the auto-planning included the planning target volume PTV, bladder, bowel bag, femoral heads and rectum. The automatic planning was performed by mCycle implemented in the Monaco Elekta Solutions AB Monaco Research Version (v6.09.00), in which the lexicographic and the multi criterial-optimization are coupled with Monte Carlo calculation. Wish-list 1 was tuned according to the institutional clinical protocol to get wish-list 2 to obtain an optimal plan in a single optimization for all patient each with three different groups of contouring type. Data was exported from the TPS and imported in ProKnow. The impact of mCycle according to different contouring type were compared in terms of dose distribution and modulation complexity score. Their clinical acceptability was assessed by evaluating the plan quality index.

Results: The 120 automated planning task according to different contouring type using the wish-list 2 took 5 to 10 working days to complete clinically acceptable plans. The final dose calculation time can be estimated to 35 to 45 minutes to complete each plan. The dose comparison showed a comparable OAR spare. The PTV coverage were similar according to different contouring type auto, auto-manual and manual ($V_{95\%}$:94.567,94.539,94.748, $p>0.05$). The OAR bowel bag minus PTV no significant difference has been registered except for right femur head which registered significant differences as follows (V_{45Gy}(cc): auto 200; auto-manual 342; manual 268, $p>0.005$) and ($D_{5\%}$(Gy): auto 0.544; auto-manual 0.767; manual 1.273, $p<0.05$) respectively. The median plan quality index and MSC was (PQI: auto 36.99[2.87-52.53]; auto-manual 33.25[1.04-46.45]; manual 32.11[2.16-49.68], $p>0.05$) and (auto 0.263[0.192-0.280]; auto-manual 0.239[0.195-0.271]; 0.234[0.199-0.276], $p>0.05$) respectively, no significant difference has been registered.

Conclusion:mCycle plans according to auto, auto-manual and manual contouring of OAR were comparable to each other, with an exception of the OAR right femur head sparing which was not similar. More complex but clinically acceptable-like plans were registered similar.

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