Abstract

Evaluation of daily dose and identification of sources of error in Volumetric Modulated Arc Therapy treatments with an EPID-based in vivo dosimetry system

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The incidence of oncological diseases and their severity recorded in recent years, have led to the necessity of developing new treatment techniques with increasingly complexity, which will satisfy the clinical requirements, ensuring an effective treatment of the tumor volume, protecting as much as possible the surrounding healthy organs. The technological evolution has brought, besides all the benefits of a treatment and certain problems related to the delivery of high doses of radiation, which leads to the necessity of implementing a well-structured quality assurance program. In addition to the quality controls (QC) that ensures the proper functioning of the equipment, an important role is played by the patient specific quality assurance, which implies pre-treatment QC, but especially the control of the doses delivered every day. A patient specific dose QA should assure that the clinical impact of treatment on the patient, due to the overall performance of treatment machine and all human factors, does not deviate significantly from what is planned [1]. This approach, known as in vivo dosimetry method, has the role of checking every day the correspondence between the planned dose and the dose actually delivered to the patient. Over time, various detection systems have been used for point dose measurement, but the use of EPID device as a dosimeter has exceeded the limitations encountered in previous systems[2].

The main aim of this study is based on the use of an EPID-based in vivo dosimetry system for analysis of the discrepancies between planned and delivered treatment plans, to identify possible sources of error in VMAT treatments.

Materials and methods

For this study, measurements are performed with a TrueBeam STx linac (Varian Medical System, Palo Alto, CA) using a 6MV photon beam and equipped with an amorphous silicon (aSi) flat panel (aS1000). The treatment plans were calculated by using the Analytical Anisotopic Algorithm (AAA) algorithm which is implemented in the Eclipse TPS. All images

acquired during radiotherapy treatment fractions were analyzed through the dedicated software, PerFRACTION, (SunCHECK platform from Sun Nuclear Corporation) intended to collect, detect, compare, analyze, display and store radiotherapy QA and dosimetry data, being projected to allow the detection of errors that can occur in the delivery of a patient's radiation therapy treatment. The software utilizes information detected from the treatment beam as it exits the patient to compare the treatment characteristics between fractions, thus providing a consistency check on the daily delivery of treatment. PF automates all Patient QA needs, from secondary Checks of treatment plans (DoseCHECK) to Pre-treatment QA (Fraction 0) and In Vivo Monitoring (Fraction n), using either EPID and/or Log File data (3D analysis), or EPID data for independent 2D planar analysis. PF software provides two methods of analysis of the treatment plans.

- **2D task consists** of a 2D comparison between a transmitted EPID image converted to an absolute dose map and an expected transit dose map generated from the RT Plan. In this mode could be detected possible errors and issues related to machine delivery, patient setup, patient movement, and anatomical issues, giving the results in terms of gamma index.
- **3D task performs** a dose reconstruction based on the information concerning the multi-leaf collimator (MLC) and collimator positions obtained by analyzing the EPID images with a propriety of edge detection algorithm, and on the information available into the machine log files, such as the MUs and the gantry angles. For 3D analysis acquisition, the results can be viewed in terms of absolute and relative dose at isocenter, 3D global gamma index and DVH calculated on daily CBCT or planning CT. This task takes into account the variations of setup, anatomical changes of the patient, possible variations of the MLC, the differences in gantry rotation and of the beam delivery. In this study dosimetric analyzes were performed on a wide range of treatment plans, the pathologies treated being classified according to the anatomical district, such as: lung and mediastinum, partial breast irradiation, prostate, abdomen and pelvis, head and neck, palliative, gynecological, and brain [3].

Results and discussions

The results obtained in the study carried out at the Candiolo Cancer Institute (IRCCS-FPO, Candiolo) are presented, being introduced according to the three tasks and methods within the perFRACTION software used for analysis (DoseCHECK, 3D Fraction N, and 2D Fraction N).

DoseCheck - To eliminate the contribution due to the differences between two algorithms used, AAA of the TPS and SDC of the software PerFRACTION, the first step is represented by an independent secondary calculation of all VMAT treatment plans used with

DoseCHECK task. The results was expressed in terms of dose difference to the isocenter and the gamma index. The first set of global gamma results (3%/3mm, TH=10%) obtained for 128 VMAT treatment plans, shown a good agreement between two calculation algorithms, since the mean value of (99.1 ± 0.8) % obtained, In terms of isocenter dose, the mean value of (1.9 ± 0.8)% was below the 3% alarm threshold. Considering the optimal results, the following plans 227 treatment plans were analyzed by narrowing the comparison limits of the gamma index at 2%/2mm and a TH=10%. The results shown a good mean value of (96.0 ± 4.5)%, indicating thus, a good agreement between the TPS and the online software used for analysis. From the analysis carried out, the mean value for point dose was (1.9 ± 1.0)%.

In-vivo results – 3Danalysis With 3D method dosimetry, 180 patients were followed, for a number of 1252 fractions (with a mean of about 7 fractions / patient or treatment plan), being classified in base of pathologies. The dose volume histogram was used to calculate the percentage dose difference (%DD) in the 3 representative points on PTV: mean dose (D_{mean}), coverage dose delivered at 95% of PTV ($D_{95\%}$), and maximum dose delivered at 2% of target volume ($D_{2\%}$).

The mean (%DD) for coverage index was (-1.3 ± 4.0)%, the mean (%DD) at 2% of the PTV was (1.0 ± 1.9)%, and mean (%DD) in terms of average dose delivered to PTV was (0.3±2.0)%. Interesting to note, was the diversity in the %DD between daily dose and calculated dose, classified according to the analyzed pathology and the points of interest on PTV. As a result of stratification, it was observed that pulmonary pathologies have a -4.2% coverage index under-dose, but which do not affected the mean dose (-0.3%). The same tendency to under-dose the coverage index ($D_{95\%}$) was obtained for breast treatments (-5.4%), in which the key factor was the superficial position of the target volume. At the level of the prostate treatments there was a slight overdose of the target volume for all 3 points analysed, which was due to the inadequate preparation of treatment protocol (bladder and rectal filling), and to the patient's weight loss. In the case of palliative treatments and those of the abdomen and pelvis, there was no significant %DD. Head and neck pathologies was more sensitive on the coverage index ($D_{95\%}$ = -1.0%), and less in terms of the mean dose (D_{mean} = 0.2%).

Clinically, the greatest impact on the effectiveness of RT treatment is represented by errors greater than 5%. Considering instead the total of 1252 treatment fractions analyzed, a mean (%DD) occurred only for 166 (13%) fractions, at least for one of the points of interest on PTV. It was found that the highest percentage was recorded in the case of pulmonary pathologies, followed by breast and prostate. The main sources of error founded was variations

of SSD (30%) and irregular respiratory act (39%), followed by anatomical changes (10%) and other errors of positioning of patients.

2D analysis results for VMAT treatment plans In vivo verification test using the integrated EPID images, were performed in the case of 36 patients, for a number of 175 fractions (approximate 5 fractions/patient), being classified according to pathologies.The results for which the analysis parameters have been fixed at 3%/3mm and TH=10%, with an acceptable limit of 85% revealed a good outcome in terms of treatment delivery (γ_{mean}=94.6% ± 4.2)%. It is observed that the highest mean value was obtained in the case of breast treatments (97.2±1.2), followed by the lungs (96.5±2.7) and those of head and neck level (96.1±3.1). This method, not using the CBCT images, is less sensitive to the areas of high gradient, such as tissue/air, resulting as it is a better indicator that 3D method for this type of treatments.

Conclusions With this result, DC task from PerFRACTION has proved very useful in verifying dose calculation, giving reliability to the treatment plans calculated with the TPS. Regarding in vivo dosimetry, the EPID-based system has proven to be a good dosimetric instrument, able to identify a wide range of errors intercepted during the radiotherapy treatment, from errors related to the patient's setup, to different anatomical changes related to the weight loss or to variations of target volume. No geometric or dosimetric errors related to the treatment machine were found, the patient-based error is the dominant one.

Bibliography

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[3] HELP, official page of PerFRACTION software