Dedicated Linac Commissioning for Radiosurgery Treatments, in Albania

Lulzime Daci
Radiotherapy Department
Hospital Trust
3-Bodø,Norway
lulzime.daci@nordlandssykehuset.no

Prof.Partizan Malkaj
Faculty of Mathematics Engineering and Physics Engineering
Tirana, Albania
malkaj_p@hotmail.com

***Abstract*—LINAC-based radiosurgery has been commissioned at Mother Teresa University Hospital with the primary aim to treat the tumors, vascular lesions and functional disorders. Due to the size and shape of such targets, small cones are suitable for this technique. Measurements were made to characterize the dosimetric properties of small fields collimators set for PRIMUS Oncor Linac(Siemens). In addition, the geometric and dosimetric accuracy of linac was verified when used with Radionics planning system. Materials/Methods: A set of 12 cones (12.5-40.0mm diameter) was commissioned with the linac and modeled into the planning system Xknife for energies 6MV and 7MV flattening filter free. Output factors, TMRs and OARs were collected in PTW-MP3 water phantom, using PTW Pin point 0.016cm3 chamber. Isocenter position variations with table, gantry, and collimator rotation were found to be <0.5 mm, with a compounded accuracy of less than 1.0 mm. For TPS commissioning various verifications was performed: MU calculations accuracy, isocentre localization, output factors using OSL dosimetry by the IAEA and grafchromic films. Conclusions: Due to the difficulty of measuring small fields verifications and external audits were performed. The 6MV and 7MV FFF beams does not differ dosimetricaly much for small fields, but using FFF improves treatments delivery, reducing treatment times due to high dose rate. Our first clinical results are consistent and indicate a favorable evolution. They confirm that the combination of accuracy, conformity and homogeneity of this system makes it possible to apply safely single fractionated radiosurgery as a good alternative to selected patient**

Keywords—dosimetry; radiosurgery; filter flatering free;

I. Introduction

Radiosurgery was originally introduced in 1951 by the Swedish neurosurgeon Lars Leksell. It is defined as a single high dose fraction of radiation, stereotactically directed to an intracranial region of interest. Since the beginning, it was considered an ablative technique for the treatment of lesions or well-defined areas in the brain, focusing with high precision high-dose ionization radiation. Now days they are different equipments in the market from different vendors that deliver such treatments like Gama-knife, Linear accelerators, Cyberknife, or Tomotherapy.

Although the radiosurgery has a long history around the world, it was not until November 2013 that the technique was introduced in Albania. The first linear accelerator at Mother Teresa University Hospital was installed at neurosurgery service, and the main aim was to treat the tumors, vascular lesions and functional disorders. The technique is linac based that means that it delivers a narrow collimated X ray beam while the gantry rotates around the target. The linac is a Siemens Oncor Impresion and up to now it is the only one in public sector.

The linac has two photon energies: a 6MV and a 7MV without the flattering filter (FFF) with a dose rate up to 1000Mu/min. At the time of installation the linac was only radiosurgery dedicated.

The hardware for radiosurgery is from Radionics and consists on stereotactic radiosurgery system of 12 circular shaped cones, ranging from 12.5 to 40 mm diameter in 2.5 mm steps. The cones are inserted in a base plate mounted on the collimator head and are used for arc treatments. The Radionics three-dimensional treatment planning system that employs the Xknife dose algorithm is used for treatment planning. A Siemens Somatom Plus CT scanner and MRI are used for imaging, target volume delineation, and volume reconstruction, through Dicom connection. Each system is individually tested for accuracy and reproducibility.

II. Materials and Methods

Basic requirements for SRS are mechanical precision, accurate localization, accurate and optimal dose calculation and patient safety. During the commissioning of isocentric linac-based radiosurgery we verified and measured radiation and mechanical characteristics of linac.

A. *Geometrical Accuracy*

To test the system for geometrical accuracies, four ultra-fine lasers are mounted on the walls and ceiling. The accuracy of gantry, collimator, and couch rotation was accurately verified during commissioning of the SRS facility. The accuracy in alignment and verification of isocenter and target was carried out as described in Radionics operator manual and international protocols. Routine quality assurance includes the visual and film test verification of the isocenter position with the Radionics, laser target localizer frame (LTLF) rectilinear phantom pointer (RLPP) and the radiopaque ball pointer. To check the gantry rotation, the frame was mounted on the coach with the coordinates to zero. The table was moved in order to align the lasers to the frame with the use of the scribed lines on the laser target pointer (LTP). The laser target pointer was replaced with a radio opaque ball pointer and aligned in the center for the smallest cone. Films were irradiated with various gantry angles and evaluated with imageJ free software. Same procedure was done rotating the coach in (0, 90 and 270º) in order to verify the coach position. The lasers were checked to be within scribe lines of the laser target pointer. Isocenter position variations with table, gantry, and collimator rotation were found to be <0.5 mm, with a compounded accuracy of less than 1.0 mm.

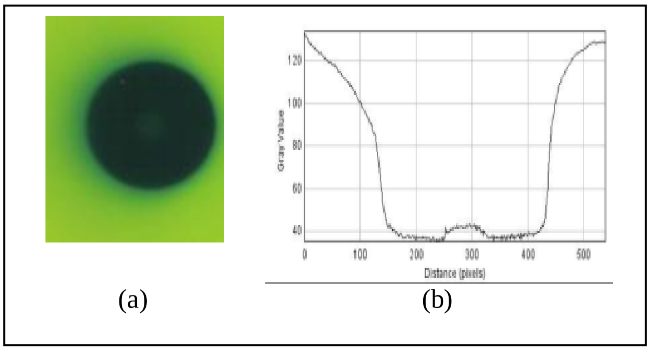

Fig.1 (a) isocenter verification with graphcromic film (b) evaluation of isocenter with ImageJ

B. Dosimetry measurements

We have required two sets of beam measurements during the introducing linac-based radiosurgery in a clinical department: The Basic physical parameters of stationary beams collimated for radiosurgery and the dose distribution obtained with the radiosurgical technique to be used clinically. The first measurement provides the basic data for the 3D treatment planning software, and the second set, tests the treatment planning software and verifies the important the mechanical characteristics of Linac, since the measured accuracy of the dose delivery technique depends on the alignment of the radiosurgical collimator as well as on the mechanical condition of the gantry and couch rotation.

The linac was calibrated to give 1Gy per 100 MU for a standard open field of 10x10 cm using a source to skin distance of 100 cm. Other important dosimetric parameters such as tissue maximum ratio (TMR), off axis ratio (OAR) and cone factor (OF) needed for SRS dosimetry were accurately measured for both energies 6MV, 7MV FFF. All the measurements were done with a pin-point ionization chamber using PTW dosimetry system as the only detector available in the clinic with high resolution.

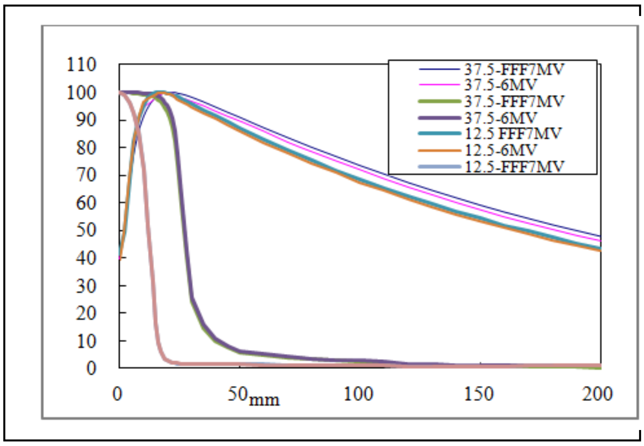

Fig.2 TMR and OAR for 6MV and 7MV FFF, for smallest cone 12.5 mm and 37.5 mm.

The TMR for both energies are given and the variation of Dmax, that change with the cone size can be treated at a constant depth of 1.5 cm within the limits of experimental accuracy. The measured TMR data were fitted for larger cones the TMR data were verified to be within ±0.5%. It was reported that at 10 cm depth, approximately 8% increase in TMR can be observed from the 12.5 mm cone to the 40 mm cone. In general, the larger cones have higher TMR values. For our dedicated system the variation in TMR is limited to less than 5% between the 12.5mm -and 40.0mm cones. The profiles were measured and tabulated for the TPS. There is no significant difference on the profiles when compared 6MV beam with 7MV FFF.

Cone output factors were verified with OSL dosimetry provided by the IAEA giving a difference of less than 1.01%. The IAEA TLD audit gave a variation of 0.5% for both energies for the output of the Linear accelerator.

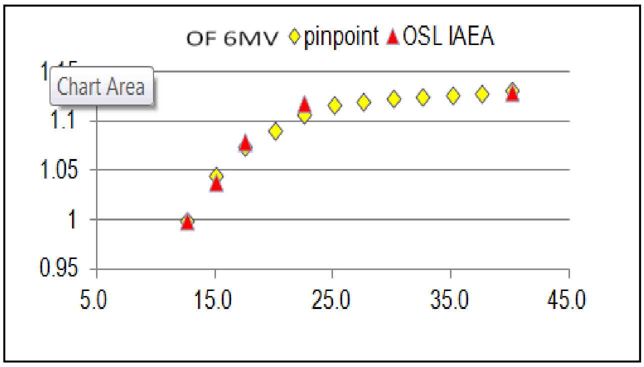

Fig.3 OF measured with pin point and OSL IAEA audit

The data was processed and was sent to the vendor in order to insert them into the TPS. The geometrical QA for imaging was performed, and acceptance test of the software resulted with an error of image distortion of 0.2 mm.

An end-to-end test was performed before the first patient using a in-house phantom with the aim to identify the potential errors in the treatment chain workflow. A grafchromic film was inserted and fixed inside the phantom, it was pinned the location of radio opaque marker was. The phantom followed all the steps of a patient treatment. And the results showed that the beam heats the target with a high precision.

III. CLINICAL WORKFLOW AND CASES

Clinical workflow is given including different steps and also multidisciplinary team.

The procedure of radiosurgery begins with fixing the stereotactic frame in the head of the patient and taking CT images, which were transferred to the X-Knife workstation. Then the neurosurgeon and neuro-radiologist contour in every image the lesion as well as organs at risk (optic pathways, brainstem, ocular globes, lens, etc.) using initially fused images with previously done magnetic resonance of the patient. The physicist defines the plan combining the gantry and couch's movements to have a optimized dose distribution covering the target and sparing the organs at risks. The plan is evaluated by the team and when approved the data is transferred at Record and verify system. The isocenter parameters are inserted at the frame localization and checked independently by two persons. Independent MU calculations and isocenter verification using the Winston-Lutz test are done before the treatment takes place. The clinical follow up is performed at the first, third and sixth month and then annually. Radiology studies are required after 6 months, first year and then depending on the disease under treatment.

Age sex	Pathology	Vol. cm^3	Dose Gy	Arcs	Ø Cones mm	E MeV	Vol % covered
49 F	AVM	1.53	16	6	22.5	7 FFF	90
38 M	AVM	0.48	16	5	17.5/15	7 FFF	91
57 M	Vestibular schwanoma	1	13	3	22.5	7 FFF	98
46 F	Sphenoorbit meningioma	2.1	14	5	25	7 FFF	95
56 F	Cavernous sinus meningoma	1.48	14	8	15/ 12.5	7 FFF	96
46 M	Clival cordoma	1.59	15	4	22.5	7 FFF	90
51 F	Pituitary adenoma	1.18	14	4	22.5	7 FFF	98.5
61 F	Pituitary adenoma	0.2	14	4	15	7 FFF	100
42 F	Pituitary adenoma	0.58	14	4	17.5	7 FFF	100
50 F	Pituitary adenoma	4.1	14	8	27.5/25/12.5	6	85.4

Table I. *Summary of clinical and dosimetric data of the first ten patients treated with radiosurgery in Albania*

The first ten patients were treated in the first month at the X-Knife Unit. There were seven females and tree males, from 38 to 61 years old. The prescribed doses ranged from 13Gy to 16Gy. Treated tumor volumes ranged from 0.2cm3 to 4.1cm3. The number of arcs used was from 3 to 8 according to the difficulty of the case and only 2 cases were realized with 2 isocenter. Collimators with different sizes from 12.5 mm to 27.5 mm were used. In all cases, satisfactory coverage of the required tumor volume was achieved, ranging from 91% to 100% of the tumor volume, except for the first case with a large pituitary adenoma where the required coverage dose was achieved in 85.4%. Out of the 10 cases, only 2 had headache on the first night after treatment and it was treated with an anti-inflammatory. There were no other acute effects. The next day all the patients left the hospital and after one year follow up there have been no side effects reported.

Fig 4. First SRS treatment in Albania, November 2013

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