Original Research Article

Commissioning of two different algorithms for stereotactic Radiosurgery M6 FI+ CyberKnife system

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Abstract

Introduction: Cyber Knife M6 FI+ a very precise robotic stereotactic radiosurgery system which is capable of delivering very high radiation dose to the tumour while minimizing radiation exposure to normal organs and tissues. Multi Plan treatment planning system is used with the CyberKnife unit and the algorithms used for optimization are Ray-Tracing and Monte Carlo. Our CyberKnife M6 FI+ system commissioning is done as per the vendor recommendation and meeting the local regulatory guidelines. **Materials and Methods:** Clinical beam data measurement is carried out using Radiation Field Analyzer, Diode E, Pinpoint chamber, Semiflex ionization chamber and Unidose E Electrometer. FC-65 ionization chamber used in absolute dose calibration. The mechanical accuracy of the robot and image stability was verified using Radiochromic film (EBT3), E2E and Iris QA toolkits along with software. StereoPHAN is used for the patient-specific QA point dose measurement. **Results:** Tissue phantom ratio, Off-centre ratio, Output factor, Percentage depth dose, open beam profile and absolute dose calibration are done as per the protocols. E2E performed for two different modes- static and motion. Iris aperture size measured for all the field sizes. The patient-specific QA delivered for both algorithms. **Discussion:** Clinical beam data measurements are within ±1% of composite data set, overall standard deviation for Output Factors of the fixed and Iris collimators are 0.0026 and 0.0063. The absolute dose was calibrated to 1cGy per MU. E2E, Iris QA and Laser and radiation coincidence values are within the tolerance. Patient-specific QA point dose measurement variation for Ray-Tracing and Monte Carlo is 3% and 2%. **Conclusion:** These exercises are mandatory to achieve the accurate, precise and high quality of treatment which also includes patient safety.

Keywords: Commissioning, Cyberknife, Monte Carlo, Ray-Tracing, Radiosurgery

Introduction

A CyberKnife M6 FI+ robotic stereotactic radiosurgery system (Accuray, Sunnyvale, CA), treatment unit in which miniature type linear accelerator has mounted on an industrial robot [1,2]. CyberKnife with sub-millimetre accuracy it can treat tumours anywhere in the body like brain, spine, liver, prostate, lung with the help of frameless real-time image guidance technology and computer-controlled robotics [1,3]. Due to the high degree of accuracy and precision, the CyberKnife system is capable of delivering a very high radiation dose to the target with minimal dose to the nearest critical organs and surrounding normal tissues [4].

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The CyberKnife linear accelerator emits 6 MV photon with flatting filter free (FFF) at constant dose rate of 1000 MU/min, 9.3 GHz X Band [3]. The compact lightweight linac head is attached to a robotic arm that is producing the non-isocentric beam angles during treatment with 6 degrees of freedom. There are two different types of secondary collimator systems- Fixed and Iris with 12 different aperture sizes 5, 7.5, 10, 12.5, 15, 20, 25, 30, 35, 40, 50 and 60mm [3].

Fixed collimators are having static apertures in size and aperture of Iris collimator is adjustable under computer control. It contains 2 stacked hexagonal banks of tungsten segments that together produce a 12 sided aperture a regular dodecagon [3,5].

Commissioning beam data are very important to get a good treatment outcome. Because these measured data consider as a reference and simultaneously used in the MultiPlan treatment planning system. The quantities required to measure for commissioning and quality assurance purposes of a CyberKnife system include absolute dose calculation, using the IAEA TRS-398 protocol [6]. According to Accuray commissioning recommendation, mechanical accuracy of the robot, ~~and~~ image stability and patient-specific QA (point dose measurement), Clinical dosimetry measurements such as tissue-phantom ratios (TPRs), off-center ratio (OCRs), secondary collimator output factors (OFs), percentage depth dose (PDD) and open beam profile presented here [3,7]. All the measurement results compared with Accuray composite beam data set and tolerance values.

Materials and Methods

All the clinical beam data (Ray-Tracing and Monte Carlo) acquired using

- Radiation Field Analyzer a computer-controlled measuring system (SCANLIFT MP3-Therapy beam analyzer: PTW, Freiburg, Germany),
- TM60017 Diode, TM31014 Pinpoint chamber, TM31010 Semiflex ionization chamber (PTW) and
- Unidose E Electrometer (PTW)

The absolute dose calibration of the accelerator output was accomplished using

- TM30013 Farmer chamber (PTW) and
- Unidose E Electrometer

The mechanical accuracy of the robot and image stability was verified using

- Radiochromic film (EBT3, Ashland Speciality Ingredients, Bridgewater, NJ- 08807)
- Film Ball Cube II (EBT2, H.A.Y.E.S. Manufacturing Services, Sunnyvale, CA-95054)
- Mini Ball Cube II and XLT Phantom kit films (EBT2)
- EPSON Perfection V800 photo scanner
- Head and neck phantom, Synchrony QA tool (Accuray, Sunnyvale, CA-94089)
- CIRS-Xsight lung tracking phantom kit & 4D planning phantom (CIRS Tissue Simulation & Phantom Technology, Norfolk, USA)
- Iris QA software and E2E software (Accuray)

The patient-specific QA (point dose measurement) was verified using

- StereoPHAN (Sun Nuclear, 3275 Sun tree Blvd, Melbourne, FL 32940)
- TM31014 Pinpoint chamber

Results

Clinical beam data measurements are performed as per the vendor recommendations for the commissioning of two different algorithms, Ray-Tracing and Monte Carlo [3]. The Ray-Tracing algorithm needs TPR, OCR and OF measurements [3,7]. Monte Carlo algorithm PDD and Open field profiles in addition to the Ray-Tracing algorithm [3].

A.1.TPR Measurement

The Tissue phantom ratio (TPR) is the ratio of absorbed dose at a given point to the dose to the dose at a fixed reference depth using constant SAD [8]. The reference depth for the CyberKnife system is 15mm (Dmax) for all collimator sizes and SAD is 800mm [3]. The TPR measurement was carried out using Diode E position in the RFA water phantom.TPR measurement taken in different depth 0, 3, 5, 8, 10, 13, 20, 30, 50, 100, 150, 200, 250 and 300mm for all the field sizes for both collimators at constant SAD 800mm (Table 1 and 2). We use a cubic spline fit to generate a TPR curve depths from 0 to 300mm and normalize the values for each collimator to the depth of 15mm as shown in Figure 1 and 2.

A.2.OCR Measurement

The OCR at a particular depth is the ratio of absorbed dose at a given off-axis point relative to the dose at central axis [8]. OCR measurement carried out using field chamber of Diode E, reference chamber of the Semiflex ionization chamber and water phantom. A central check carried out at two different depth 15 mm and 200 mm for using the 60mm collimator at SSD of 800mm. Normalization is done to align the radiation beam center to the detector center. Fixed collimator OCR measured by conducting orthogonal scans across at the depth of 15mm and 100mm. In Iris collimator same like Fixed collimator scans and additionally rotate the linac head in 15 degrees and generate orthogonal scans in the same setup. Because Iris collimator having a Dodecagonal aperture [3]. OCR values were calculated by average in each side of the cross plan and in plan scans. Therefore each entry in the OCR data table is the average of four measurement values for fixed collimator and eight measurement values for Iris collimator as shown in Figure 3 and 4.

A.3.Output Factors

The output factor (OF) is the ratio of absorbed dose at a particular field size relative to the dose at a reference field size [3,8]. The reference field size for the CyberKnife system is based on the 60mm fixed collimator at SAD 800mm [2]. The measurement carried out by using the Diode E, water phantom and Unidose E electrometer. All the measurement carried out at the depth of 15mm (Dmax). Meter reading is taken five times continually for each field size and calculated the average value. Both secondary collimators Fixed and Iris average value of each field size is normalized to reference field size of 60mm Fixed collimator value [3]. All the measured values are compared with the composite data set (Accuray) as shown in Table 3.

A.4. PDD Measurement

PDD is defined as the ratio of the absorbed dose at any depth to the absorbed at a reference depth (D_{max}) [8]. PDD measurements are performed using 60mm fixed collimator. Check the center of the linac beam at two depths in the water phantom 100 mm and 200 mm to verify that the linac beam is pointing straight down. The PDD measurement is acquired at the depth of 1 mm to 300 mm.

A.5. Open Field Profile

Open field profile measurements are done with no collimators attached to the fixed collimator housing. A diode detector is positioned in the water phantom at the depth of 25mm from the water surface and SAD 800mm [3]. Center check is done with PTW MedPhysto software to make sure the origin of the water phantom is in coincident with the central axis of the linac radiation beam. A set of orthogonal scan profiles are acquired extending from -80 mm to +80mm in each direction.

A. The absolute dose calibration of the accelerator output

Absolute dose calibration of the CyberKnife was accomplished in accord with the IAEA TRS 398 protocol. The CyberKnife output was calibrated to deliver 1cGy per MU under reference conditions 60mm collimator, 800 mm SAD. Absolute dose calibration carried using FG 65 ionization chamber, water phantom, and Unidose E electrometer. To know the $K_{Q,Q0}$ of the chamber need to find $TPR_{20,10}$. $TPR_{20,10}$ measured at two different depth 200 mm and 100 mm under the reference condition. The output measured at the reference depth of 100mm [6].

The Output formalism is

$D_{Q,\ 100\ mm} = MR \times N_{D,W} \times K_{T,P} \times K_{Pol} \times K_{ion} \times K_{Q,Q0}$

where $D_Q = D_{Q,100\ mm}$/ TPR (100 mm), $D_{Q,100\ mm}$ = Absolute dose at 100 mm depth, D_Q= Absolute dose at Dmax, MR = Electrometer Reading (nC), $N_{D,W}$= Chamber Calibration Factor (Gy/C), $K_{T,P}$=Chamber temperature and pressure correction factor, K_{Pol} = Chamber polarity correction factor, K_{ion} = ion recombination factor, $K_{Q,Q0}$ =Beam Quality Index and TPR (100mm) = Tissue phantom ratio at 100mm depth

C. The mechanical accuracy of the robot and image stability

C.1. End-to-End test

The E2E test is used to determine the total positional error for each stationary tracking mode and motion tracking mode installed on a CyberKnife system [3]. Stationary tracking modes include the 6D skull tracking system, the fiducial tracking system, and the Xsight spine tracking system. Head and Neck phantom and synchrony QA tool are used for stationary tracking mode. Motion tracking mode includes the Xsight lung tracking system and Synchrony Respiratory Tracking System. CIRS- Xsight lung tracking phantom kit is used in motion tracking system [9]. There are two orthogonal Radiochromic films loaded in phantoms.

The plans are generated according to Accuray recommendation [3] (Table 4). Both tracking modes plans are delivered with couch positional accuracy of less than 1mm and 10. EPSON Perfection V800 photo scanner was calibrated to scan the two exposed films (Axial and Sagittal) and one unexposed film. An unexposed film used to subtract the background during analyzing processes. E2E software is used to analyze the scanned film data (Table 5). The specification for total positional error for the E2E test is ≤ 0.95 mm for all stationary and motion tracking modes and our results were well within the prescribed limits. [3].

C.2. Laser and radiation coincidence test

The CyberKnife system uses a pinhole laser that is coincident with the radiation field central axis. The LINAC laser is reflected off an adjustable mirror and aligned to the mechanical center of the collimators. Laser and radiation coincidence test carried out using 35mm fixed collimator and two radiochromic films at two different distance.

The first film exposed 800MU at SDD 800 mm the laser point marked in film, the same procedure repeated for the second film also only change in the SDD 1600 mm. EPSON Perfection V800 photo scanner was used to scan the exposed film and ImageJ software used to analyze the scanned data (Table 6). The tolerance value is < 1mm at SDD 800mm and < 2mm at SDD 1600mm [3].

C.2. Iris QA

Iris is one of the secondary collimators in CyberKnife system and its aperture size changes are computer controlled. To verify the aperture size in Iris collimator radiochromic film, Iris QA, Iris QA hardware accessories are used [3,10]. Birdcage assembly attached to collimator system and Iris QA film mount placed on birdcage [3,5]. Radiochromic film position on film mount, Build up 15 mm kept the top of the film. Irradiate the film with 600 MU. Each aperture sizes are repeated three times.

The same step up needs to do for 15 mm fixed collimator for Iris QA analysis purpose. The irradiated films and blank films are scanned using EPSON Perfection V800 photo scanner. The Iris QA software used to analyze the scanned data and is as shown in (Table 7). The tolerance should be less than ± 2mm of baseline values [3,5].

D. The patient specific QA (point dose measurement)

The patient specification QA has done for both algorithms Ray-Tracing and Monte Carlo using StereoPHAN, Pinpoint chamber and Unidose E Electrometer. The QA plan generated in Multiplan MD suite version 5.3.0 and noted the planned point dose value for both algorithms. StereoPHAN and pinpoint chamber set in the treatment position and deliver the 2000MU for warm up.

After the zeroing QA plans are delivered. Electrometer reading, temperature, and pressure values are noted. Measured Point dose values are found using the absolute dose formalism. The percentage of variation between planned value and the measured value should be less than is ±5% [3]. The measurement setup is as shown in Figure 5.

Table-1: TPR value for all fixed collimators and normalized value to 15 mm depth.

Depth (mm)	Collimators (mm)										
	5	**7.5**	**10**	**12.5**	**15**	**20**	**25**	**30**	**35**	**40**	**60**
0	0.566	0.51	0.487	0.474	0.463	0.46	0.459	0.46	0.462	0.462	0.483
3	0.824	0.773	0.717	0.706	0.7	0.678	0.678	0.683	0.681	0.693	0.695
5	0.94	0.897	0.856	0.843	0.835	0.818	0.813	0.815	0.811	0.816	0.82
8	1.005	0.981	0.956	0.948	0.937	0.924	0.919	0.922	0.92	0.923	0.919
10	1.013	0.999	0.985	0.977	0.969	0.968	0.959	0.96	0.959	0.957	0.959
13	1.008	1.005	0.999	1	0.998	0.992	0.991	0.989	0.989	0.989	0.989
15	1	1	1	1	1	1	1	1	1	1	1
20	0.982	0.986	0.986	0.987	0.99	0.998	1	1.001	1.004	0.999	0.999
30	0.929	0.936	0.936	0.947	0.951	0.961	0.966	0.97	0.974	0.97	0.981
50	0.832	0.843	0.847	0.86	0.859	0.878	0.884	0.888	0.895	0.898	0.909
100	0.638	0.651	0.656	0.667	0.672	0.687	0.699	0.705	0.713	0.718	0.74
150	0.496	0.506	0.514	0.526	0.527	0.54	0.552	0.557	0.562	0.568	0.593
200	0.382	0.399	0.405	0.414	0.418	0.429	0.439	0.442	0.45	0.456	0.475
250	0.304	0.314	0.321	0.33	0.333	0.342	0.349	0.354	0.359	0.364	0.382
300	0.241	0.252	0.257	0.264	0.269	0.276	0.281	0.285	0.289	0.293	0.307

Table-2: TPR value for all Iris apertures and normalized value to 15 mm depth.

Depth (mm)	Collimators (mm)										
	5	7.5	10	12.5	15	20	25	30	35	40	60
0	0.557	0.517	0.483	0.473	0.462	0.46	0.459	0.461	0.461	0.461	0.474
3	0.794	0.749	0.714	0.69	0.677	0.67	0.673	0.674	0.671	0.669	0.671
5	0.925	0.884	0.859	0.828	0.822	0.81	0.813	0.8	0.811	0.809	0.81
8	0.993	0.975	0.952	0.943	0.933	0.925	0.923	0.919	0.914	0.914	0.916
10	1.005	1	0.985	0.976	0.968	0.96	0.965	0.961	0.959	0.955	0.96
13	1.006	1.005	0.995	0.998	0.996	0.989	0.991	0.993	0.989	0.989	0.992
15	1	1	1	1	1	1.002	1	1	1	1	1
20	0.977	0.985	0.989	0.989	0.996	1	1.005	1.002	1.006	0.998	1.011
30	0.931	0.934	0.938	0.946	0.953	0.965	0.973	0.97	0.971	0.975	0.98
50	0.832	0.846	0.853	0.862	0.862	0.877	0.891	0.89	0.898	0.898	0.915
100	0.64	0.649	0.658	0.67	0.673	0.686	0.701	0.706	0.713	0.717	0.742
150	0.495	0.507	0.517	0.525	0.533	0.544	0.551	0.557	0.565	0.565	0.596
200	0.387	0.4	0.406	0.414	0.417	0.432	0.439	0.445	0.45	0.453	0.476
250	0.306	0.312	0.323	0.331	0.333	0.342	0.35	0.354	0.36	0.362	0.382
300	0.24	0.251	0.26	0.265	0.269	0.275	0.282	0.287	0.287	0.293	0.307

Table-3: Comparison of output factors with the Accuray provided composite data

Output Factor								
Collimator Size	Fixed Cone				Iris			
	Output Factor	Composite	Ratio To Composite	Standard Deviation	Output Factor	Composite	Ratio To Composite	Standard Deviation
5.0 mm	0.680	0.675	1.008	0.031	0.551	0.541	1.018	0.052
7.5 mm	0.834	0.829	1.006	0.024	0.805	0.796	1.012	0.026
10.0 mm	0.881	0.878	1.004	0.018	0.884	0.877	1.008	0.018
12.5 mm	0.916	0.914	1.002	0.013	0.917	0.915	1.002	0.012
15.0 mm	0.939	0.938	1.001	0.008	0.939	0.938	1.000	0.009
20.0 mm	0.963	0.962	1.001	0.005	0.962	0.962	0.999	0.006
25.0 mm	0.974	0.974	1.000	0.004	0.973	0.974	0.999	0.007
30.0 mm	0.981	0.980	1.001	0.004	0.980	0.980	1.000	0.005
35.0 mm	0.986	0.985	1.001	0.003	0.985	0.985	0.999	0.006
40.0 mm	0.989	0.989	1.001	0.003	0.989	0.989	0.999	0.005
50.0 mm	0.995	0.995	1.000	0.003	0.995	0.995	0.999	0.005
60.0 mm	1.000	1.000	1.000	0	0.999	1.000	0.999	0.005

Table-4:E2E planning protocol for both collimators

Planning Constraints	Ball-cube 6D Skull Tracking	Ball-cube Fiducial Tracking	Ball-cube Synchrony with Fiducial Tracking	Mini Ball-cube X-sight Spine Tracking	Film Insert (25.4mm ball only) X-sight Lung Tracking with Synchrony
Anatomy	Head	Body	Body	Body	Body
Field Size	30 mm	25 mm	25 mm	15 mm	15 mm
Dose, cGy	600	600	600	600	600
Prescription	70%- 420cGy	70%- 420cGy	70%- 420cGy	70%- 420cGy	70%- 420cGy

Table-5:E2E analysed data values

Tracking mode	Fixed (< 0. 95 mm)	Iris (< 0. 95 mm)
6D Skull	0.45 mm	0.39 mm
Fiducial	0.56 mm	0.54 mm
Synchrony with fiducial	0.30 mm	0.35 mm
X Sight Spine	0.52 mm	0.48 mm
X Sight Lung	0.50 mm	0.45 mm

Table-6: Laser and radiation coincidence analysed data values

Collimators	SDD=800 mm	SDD=1600 mm
Fixed	0.45	1.2
Iris	0.51	1.15

Table-7: Iris apertures exposed film data measured value

Aperture size	Measured value
5 mm	4.80 mm
7.5 mm	7.33 mm
10 mm	9.84mm
12.5 mm	12.38mm
15 mm	14.90 mm
20 mm	19.91 mm
25 mm	24.95 mm
30 mm	29.98 mm
35 mm	34.90mm
40 mm	39.88 mm
50 mm	49.90 mm
60 mm	59.92mm

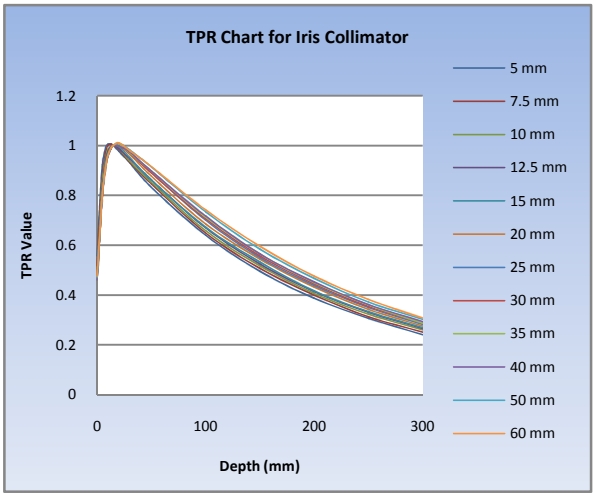

Figure-1: TPR curve for all fixed collimators and normalized value to 15 mm depth

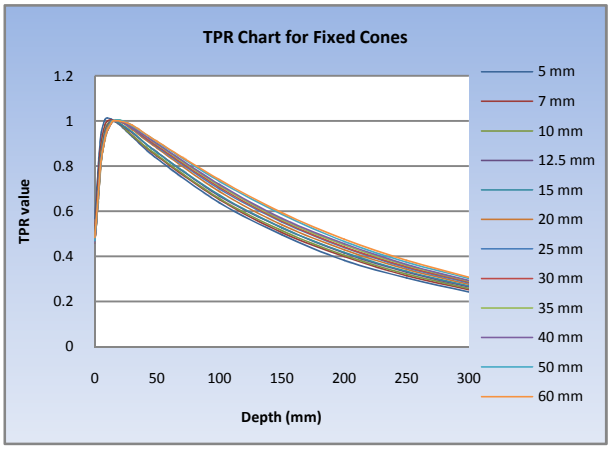

Figure-2: TPR curve for all Iris apertures and normalized value to 15 mm depth.

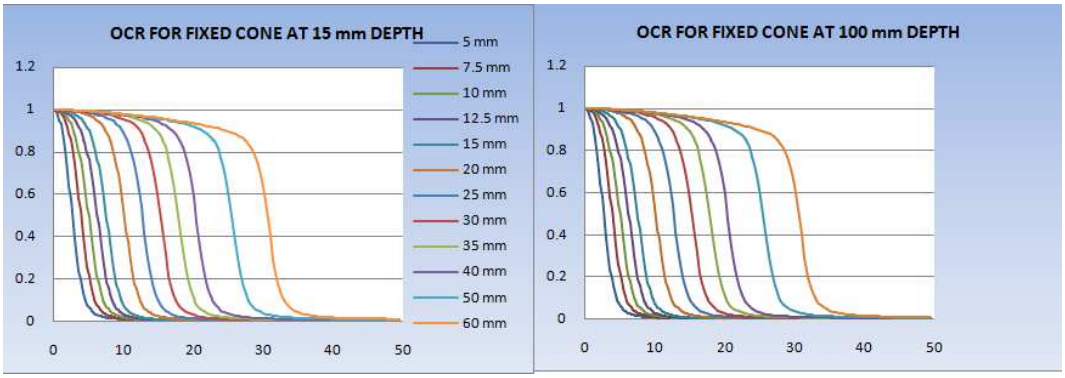

Figure-3: OCR curves for fixed collimators at 15mm and 100mm depth.

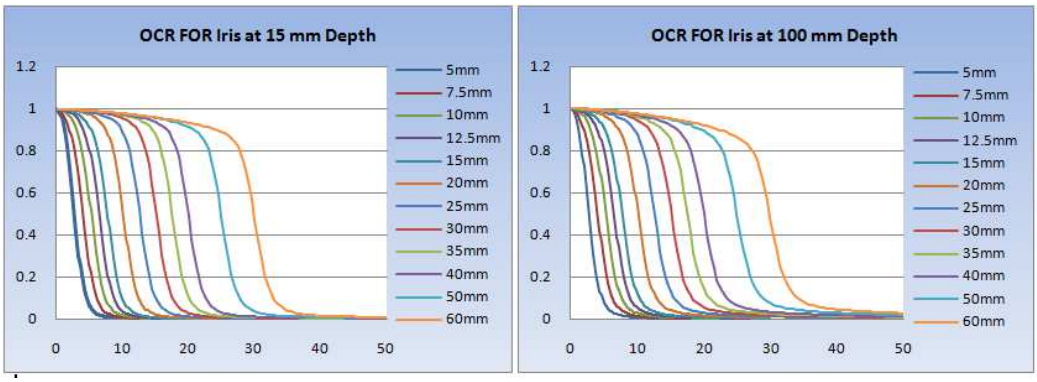

Figure-4: OCR curves for all Iris apertures at 15mm and 100mmdepth

Discussion

Stereotactic Radio surgery system is capable of delivering high dose of radiation within 1 mm of the tumour. So the system dose delivery should be very accurate and precise [1, 4, 11]. Beam data commissioning is the important parameter to achieve the accuracy and precision of the system. The same data is used to generate reference data and is also used in the treatment planning system [1,3,4,12]. The collected beam data are of the highest quality to avoid dosimetric and patient treatment error that may subsequently lead to a poor radiation outcome [12,13].

The personnel performing commissioning are recommended to have thorough knowledge about the algorithm specific beam parameters which are to be measured [4,13,14]. Subhash C [1] done the commission and acceptant test of CyberKnife. Clinical beam data measurements Tissue phantom ratio, Off axis ratio and output factor are compared with Accuray multisite data in USA. They found their results agreeing within ±2% average multisite data. In our study in addition to TPR, OAR, OF we also measured PDD and open beam profile and compared with Accuray multisite

data. The results were of excellent agreement. Each of our clinical beam data measurement was within ±1% average multisite data. A 6MV CyberKnife TPR data comparison was done by Subhash C [1] with his measurements to that of Day and Arac [15]. The result was that the difference between the measured TPR values increase with increase in the measurement depth [1]. In my study we compared both of their results with our data.

The difference in our data with that of Subhash C[1] followed the same pattern with maximum difference at 30cm depth. The output factor (OF) for both collimators was compared with composite data from Accuray (Table 3). Fixed and Iris 5mm collimator has the maximum standard deviation in output factor and highest output factor ratio to composite (0.031, 0.0052) & (1.008, 1.018). The overall standard deviation in output factor of the fixed and Iris collimators are 0.0026 and 0.0063.

Francescon [16] compared the different detectors used for measuring clinical beam data in M6 CyberKnife system. They noted that in small aperture sizes there is a variation in off axis ratio, percentage depth dose and output factor with various detectors. The Air filled chambers due to average volumetric effect underestimate measurements and semi conductor detector overestimate measurement [16,17].

In our measurements we noticed that Diode E detector over estimate the range +5% and pinpoint chamber underestimate the range -7% for 5mm collimator size.

International Atomic Energy Agency TRS 398 [6] recommendation for external beam radiotherapy is to calibrate the linac to deliver 1 cGy is equal to 1 MU at reference conditions. According to their recommend-dation the CyberKnife absolute dose was calibrated to 1cGy per MU and the beam quality index is 0.670 which was within the tolerance of 6MV photon beam value (0.676±0.009) [6].

AAPM Task Group no 135 [18] recommends E2E test as one of the major QA for mechanical accuracy of the CyberKnife system. It is recommended to perform E2E test at least for one stationary mode and one motion tracking mode on a monthly basis. The maximum difference between the centers of the planned dose and delivered dose must not exceed 0.95 mm for static treatments and 1.5 mm for motion-tracking treatments. The E2E test for stationary modes are performed with help of head phantom. An isocentric treatment plan covering the target sphere with the 70% isodose line is created. This plan is then delivered and a comparison of the position of the 70% isodose line dose distribution with the known centroid position is performed [3, 18]. The results are shown in the (Table 5). Ideally CyberKnife system well-calibrated typically performs static E2E tests on the level of 0.3–0.7 mm [18]. Our results for both stationary and motion tracking modes were well within the tolerance level.

Iris aperture size verification is among the monthly quality assurance of CyberKnife radio surgery system [3,18]. The Iris collimator consists of two stacked hexagonal banks of tungsten segments together produce a 12-sided aperture at nominal distance of 800mm. Iris is a computer-controlled collimator which benefits in improved plan quality and time efficiency [3,5,19].

Several authors recommend different techniques using ion chamber, optical image based and Radiochromic film to find out the Iris aperture size. Sarah CH [5] verifies the aperture size using the pinpoint ionization chamber. They have the base line output factor for all 12 aperture size during the commission time.

This method is economically efficient and less time consuming. Although the detector positional uncertainty is more for small collimators 5mm and 7.5 mm in this method. But in our study high resolution Radiochromic film is used to measure the different aperture sizes [3].

The results are shown in the (Table 7). With Iris aperture we found a maximum deviation to 4.80 mm for 5 mm collimator, although within the tolerance limit [3, 18]. Drawback of this method is that it is time consuming. The whole film analysis process can easily take up to 2 hours.

In stereotactic radiosurgery even a small error in treatment planning, delivery, or dosimetric can lead to poor radiation outcome. Before start of the patient treatment patient specific quality assurance should be performed [8, 20]. Our planning station have two different algorithms Monte Carlo and Ray-Tracing. Monte Carlo is more accurate compared to Ray Tracing in lung and other heterogeneous tissue [21].

Drawback of Monte Carlo is that it takes more time in dose calculation. In our study plans are generated using both algorithms and implemented in phantom. The point dose difference between planned and delivered is less than 5%. The values are well within the range given by vendor [3, 8].

Conclusion

All the clinical beam data are well in agreement, utilized as input to the Monte Carlo and Ray Tracing algorithm in Multiplan treatment planning system for further clinical use. The result of mechanical accuracy tests like E2E and Iris QA has shown good stability of machine.

Patient specific QA results gave us more confidence to deliver high radiation dose to treating patients. These exercises are mandatory to achieve the accurate, precise and high quality of treatment which also includes patient safety.

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