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EVALUATING DIFFERENCES IN GAMMA INDEX OF INTENSITY MODULATED RADIOTHERAPY PATIENT SPECIFIC QUALITY ASSURANCE BY VARYING GRID SIZES IN PATIENT PLANNING

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Abstract

Choosing an optimum grid size plays a vital role for planning in Radiotherapy cases. A minimal change of even 1mm of grid size can result in large variation in treatment planning and is reflected in quality assurance results also. The objective of this study was to estimate the variations in Gamma Index (GI) quality assurance results for patients undergoing Intensity Modulated Radiotherapy (IMRT) planning with varying grid sizes of 3mm, 5mm and 10mm respectively. We compared IMRT plans for 15 patients. 15 patients planned for IMRT were selected for this study. Out of that 5 were head and neck, 5 were pelvic and 5 were brain patients respectively. For each patient three plans were generated with three different grid sizes. The plan acceptance criteria were 95% of PTV should receive at least 95% of prescribed dose and 1% of PTV should not exceed 107% of prescribed dose. Dose for the organs at risk were respected as per the QUANTEC guidelines. After plan acceptance corresponding IMRT QA was executed by PTW 729 array detector. The gamma index results of each plan were recorded for the three different grid sizes. The passing criteria were kept being 3% dose difference and 3mm of distance to agreement for all cases. Statistical analysis used: Notable passing rate of Gamma Index result are observed for three different grid size plans. The passing criteria were kept ideal to be 3% Dose difference and 3mm distance of Distance To Agreement (DTA) for all cases We observed 3mm grid size has best passing result when compared with that of 5mm and 10mm. Using minimum and optimum grid size enhances good Patient plan and good IMRT patient specific quality assurance results.

Keywords: *Intensity Modulated Radiation Therapy, Patient Specific Quality Assurance, Gamma Index, Distance to Agreement, Linear accelerating Machine, Treatment Planning System, Planning Target Volume, Quantitative Analyses of Normal Tissue Effects in Clinics (QUANTEC).*

Key Message: *It was observed in the study that using minimum grid size in TPS gives good dose calculation which results in significantly good passing QA result, when compared to larger grid spacing. So, choose the grid spacing optimum suitable for TPS planning faster and to get best QA result by determining their own grid size parameter in hospital in spite of using vendor's specified values.*

INTRODUCTION

Radiotherapy is seeing rapid development in medical field. As part of development, Intensity Modulated Radiotherapy (IMRT) has become most mature way of doing treatment to patients. Every hospital wants to have basic technique as IMRT, except for some other reasons. In this way

Linear Accelerator has reached to every hospital and has to grow to the extent of discard of Telecobalt in near future. Also, Telecobalt has its own demerits when seen with LINAC machines.

IMRT changed the way of patient planning in Treatment Planning System (TPS) till it's being executed with doing patient specific Quality Assurance. Even the way of dose prescription by oncologists is changed by adding one more step of considering priority in organs. The patient planning is done by the planning system with the approach called as Inverse Planning. In inverse planning approach, a series of conditions as dose with limits is being given to the TPS as Constraints involving Planning Target Volume and Organs at Risk. TPS optimises the plan as desired by physicist. But in case of Forward planning which is used in conventional and 3-dimensional radiotherapy techniques, prescribed dose with weight is given and plan is obtained. Due to these reasons also IMRT stands apart from other techniques.

Different planning system uses different optimisation technique one is Direct Aperture based Optimisation (DAO) and other is Direct Machine Parameter based optimisation (DMPO). In DAO, the TPS calculates the fluence directly with respect to aperture of the machine available in the department. And next will be final dose calculation. Unlike DAO, in DMPO TPS calculates the fluence first theoretically and then calculates with respect to Machine parameter. All TPS divides each beam into smaller part know as beamlets, which can be considered as pixel volume. Each beamlet is directly associated with the grid size or grid spacing for accurate dose calculation. TPS does series of iteration to obtain optimum fluence as desired by physicist and oncologist.

There are many algorithms like pencil beam algorithm, analytical anisotropic algorithm, collapsed cone convolution algorithm etc., available for the TPS to choose for fleunce and for final dose calculation. Each algorithm has its own way of defining beam interaction with matter and corresponding correction factor for accurate dose calculation. So, the vendor of TPS chooses its appropriate algorithm to associate with system for dose calculation. There are many commercial TPS available in the market like Eclipse, Oncentra, Pinnacle, Monacco, Xio, Prowess, etc., which comes along with the Linear Accelerator, or the hospital can choose.

Even though many TPS available in the market, its physicist responsibility to choose the correct TPS suitable for their centre, considering clinical application as factor. The IMRT plan as planned in TPS is delivered using a device called Multileaf Collimators (MLC) where width of the device varies from vendor to vendor or as per hospitals selection. Each width of the device varies from 5mm to 10mm. The more minimum is the width of MLC, the better plan we get. There are also Micro Multileaf collimators (MiMLC) which can be attached as an accessory device to collimators, which has width thickness less than MLCs. The planned fluence with dose (MU) called as segments is delivered with MLCs. There are many types of IMRT delivery namely, step and shoot, dynamic, Tomo- IMRT, Arc (IMAT) deliveries

The IMRT planning in TPS starts with accurate fine contouring, where one or two PTVs may be involved or may be three also. Here the advantage of IMRT planning is that not only delivering prescribed dose to PTVs and sparing Organ At Risks, but also boosting the dose to regions or organs which may require more dose. This nature of dose prescription and planning is called as Sequential Integrated Boost (SIB). SIBs are commonly used in head and neck cases, where PTV is given higher

dose compared to the high risk and low risk nodes involved.

Plan evaluation in IMRT needs attention when compared to that of other conventional plans. Strictly dose limit is set as, 95% of PTV volume should get 95% prescribed dose and 1% of PTV volume should not exceed 107% of prescribed dose. Similarly other critical organs doses are kept to the protocol of QUANTECC. Also, conformity index and homogeneity index are checked simultaneously. Apart from this there are also possibilities that doses can be dumped or pushed into normal organ region equal to prescribed dose, which can be avoided by replanning. Whole body dose or integral dose and skin dose should also be evaluated, because of many beams entering in the body. Depending on the complexity of volume, dose and OARs, the beams are chosen, which may be 5, 7, or 9 beams. Usually, the beams are placed by avoiding parallel opposed way. Priority, Penalty, weights are the terms used by planning systems to define importance for that particular organ which can be saved from exceeding dose limits.

This many steps are taken care in IMRT pre planning and during planning. After planning and considering for plan execution with patients, patient specific QA is performed. The idea of patient specific QA is that plan which is accepted for execution is then copied to the phantom without changing any parameter. It is then calculated and executed with phantom before treatment starts. Now the result is compared and concluded. This QA is done to check the correct fluence and dose is delivered. IMRT QA as two aspects to be verified one is fluence and next is dose or the MU check which is called as point dose verification. Since IMRT plan has non uniform fluence pattern, fluence match QA is performed by comparing planned fluence with that of executed one. The fluence match is done 2 dimensional plannar (2D) and 3-dimensional volumetric comparison (3D). The commonly used fluence match QA tool is of diodes or chambers placed with 5mm or 10mm gap for field sizes covering maximum area which is of 2D. It varies with vendor to vendor. There are also films available to do fluence match verification, where films are irradiated with IMRT plans and developed. They are then analysed for the result. Also, other devices available in market like EPID based QA, software analysis with MU, Gel, TLD, etc., If the result is not satisfactory, then it should be analysed for the possible error which can also end in new replanning.

The fluence match is checked with help of scoring function called as Distance To Agreement (DTA) and Gamma Index. It involves algorithm to establish deviation in planned and executed fluence. There are also other scoring functions like Normalised Agreement Test, Gamma Analysis Tool, DVH analysis tool, etc., The fluence match result is greatly affected even when there is 1mm deviation in positioning or 1mm change in grid size while planning in TPS. So, this study evaluates the deviation that is affected due to changes in grid space or size in TPS planning.

In our centre and for our study, we have considered Monacco Treatment Planning System. The linac machine is Elekta compact machine with the capabilities of MV-EPID and Multi Leaf Collimator (MLC) of 41 Pairs each 1cm width. IMRT QA tool of PTWs 729 Array detector with Varisoft software being used.

Materials and Methods:

The study was carried out in Monacco Treatment Planning system (MTPS) which supports Monte Carlo Algorithm (MCA) and Collapsed Cone (CC) Algorithm. We used Monte Carlo Algorithm for all

patients planning. We considered 5 patients of brain, head and neck, pelvis. IMRT planning is done for these patients of totally 15. For each patient 3 plans was generated or planned by varying grid sizes of 3mm, 5mm and 10mm. These plans after being accepted by oncologist for patient treatment, they are then exported to IMRT QA phantom of PTW 729 array detectors, where it is scanned and kept as like patient CT scanning images. These exported plans in phantom are then planned with respective grid sizes and 3 plans are generated by keeping gantry, collimators 0 degrees. The PTW 729 array detector consists of 729 ion chambers of which placed 5mm gap each up to 10 x 10 sq.cm field size. After 10 x 10 sq.cm each detector placed at distance of 1cm gap. It has water equivalent material as build-up of 5mm. Above the build-up, slabs of 4.5 cm is placed, so that Source to Surface Distance is 95 cm and chamber is at isocenter. This phantom as such is scanned and imported TPS for IMRT QA calculation.

The 729-array detector is connected to the system, in which varisoft software is installed. This software enables to analyse the data between TPS and executed patient file. The default settings or protocol followed for gamma index analyse with DTA is 3 mm and 3 % dose difference for all 3 mm planning's. But for 5 mm and 10 mm planning's it is considered 5mm and 5 % dose difference in DTA with gamma index because to show uniformity in result variations and also to have acceptable passing criteria.

RESULTS

The observed result is tabulated and shown in graphical representation for each site wise.

Table 1: Head and Neck cases of passing results

Patient	3mm (3mm DTA- 3% Dose Diff.)	5mm (5mm DTA- 5% Dose Diff.)	10mm (5mm DTA- 5% Dose Diff.)
1	99.5	97.2	96.5
2	99.6	95.4	97.5
3	96.6	93.4	96.6
4	98.7	92.3	98.3
5	98.8	96.7	94.9

Table 2: Pelvis cases of passing results

Patient	3mm (3mm DTA- 3% Dose Diff.)	5mm (5mm DTA- 5% Dose Diff.)	10mm (5mm DTA- 5% Dose Diff.)
1	97.5	92.9	94
2	99.3	95.6	95.5
3	99.9	98.5	95.6
4	97.9	93.8	92.9
5	95.4	93.1	95

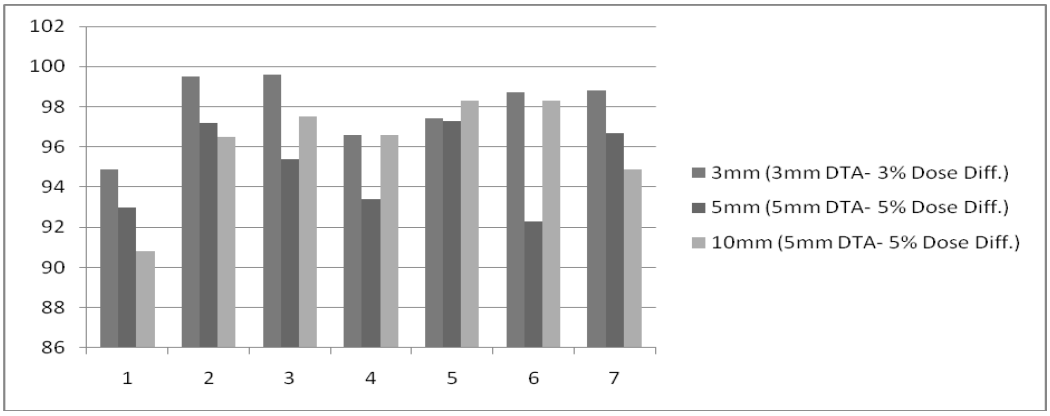
Table 3: Brain cases of passing results

Patient	3mm (3mm DTA- 3% Dose Diff.)	5mm (5mm DTA- 5% Dose Diff.)	10mm (5mm DTA- 5% Dose Diff.)
1	97.8	94.2	95.6
2	96	96	95.1
3	99.3	98.4	98.2
4	99.3	97.1	93.8

5	95.7	95.7	95.5

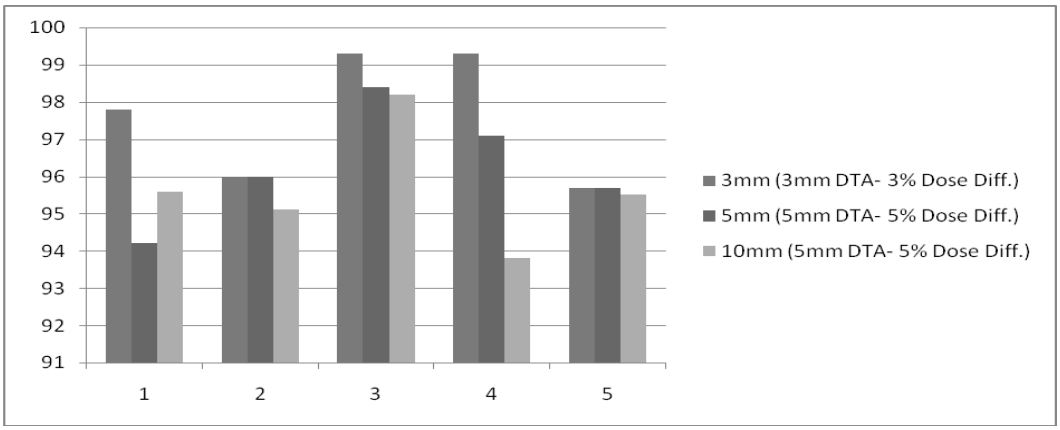
HEAD AND NECK

Graph 1: showing passing results of IMRT QA by PTW 729 Array Detector with 3mm, 5mm and 10mm grid sizes in head and neck cases



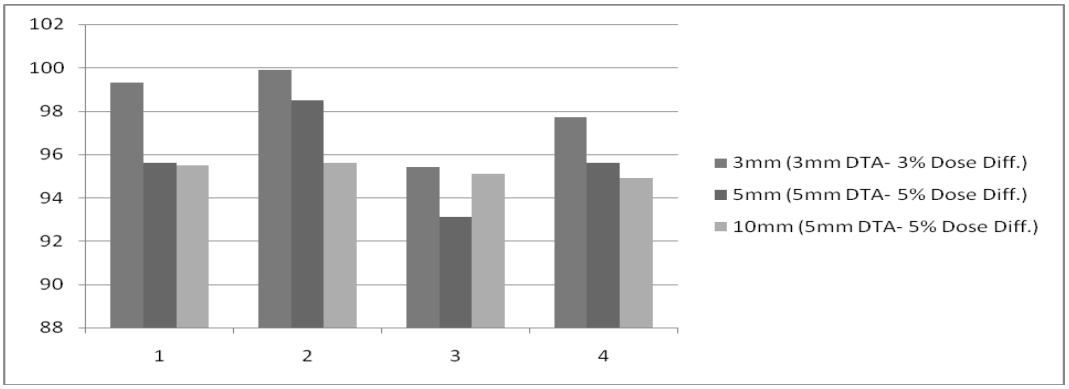
BRAIN

Graph 2: showing passing results of IMRT QA by PTW 729 Array Detector with 3mm, 5mm and 10mm grid sizes in brain cases



PELVIS

Graph 3: showing passing results of IMRT QA by PTW 729 Array Detector with 3mm, 5mm and 10mm grid sizes in pelvis cases



Also from these observed values, p value is found from the statistical analysis. The p Value is nothing but finding the statistical significance on the observed data's. Statistical Significance is the low probability of obtaining atleast as extreme results given that the null hypothesis is true[1]. It is an integral part of statistical hypothesis testing where it helps investigators to decide if a null hypothesis can be rejected [2,3].

An informal interpretation of a *p*-value, based on a significance level of about 10%, might be:

- $p \leq 0.01$: very strong presumption against null hypothesis
- $< p \leq 0.05$: strong presumption against null hypothesis
- $< p \leq 0.1$: low presumption against null hypothesis
- $p > 0.1$: no presumption against the null hypothesis.

In our study of p value calculation, we used unpaired t test, which means that there are two pairs for comparison of unequal in nature. Because we observed result as 3mm with 3% dose difference and 3 mm DTA with that of, 5mm with 5% dose difference and 5mm DTA, similarly for 10mm also. Considering 3mm as an ideal value it is compared with 5mm and 10mm in corresponding sites. The compared p values are listed and tabulated with remarks.

Table, 4: Site wise compared p value between 3mm to 5mm and 3mm to 10mm and corresponding p value remarks.

Site	Compared between	p Value	Remark
Head and Neck	3mm to 5mm	0.0101	Statistically Significant
	3mm to 10mm	0.1091	Not Statistically Significant
Pelvis	3mm to 5mm	0.0645	Not quite Statistically Significant
	3mm to 10mm	0.0038	Very Statistically Significant
Brain	3mm to 5mm	0.2864	Not Statistically Significant
	3mm to 10mm	0.1023	Not Statistically Significant

DISCUSSION

The result from the table, Graph and p values we can state that the ideal grid size value for Oncentra Treatment Planning System can be considered as 3mm to 5mm. Here one has to clearly note that there is significant result variation between 3mm to 5mm independent of site involved. However, there is not much result variation between 5mm to 10mm, which means that the TPS calculates the

dose on an average basis or independent the grid size after 5mm it calculates for the some averaged ideal value.

From the table 4 of p value, there is good significant result found for head and neck, pelvis between 3mm to 5mm. Because in head and neck cases more inhomgenity (bone, air, soft tissues) and two or three PTV volumes or lengthy volumes are involved for strict dose calculation in nature. By the way of optimisation and stringent constraints, fluence generation also becomes complex. Here is where finer calculation is involved with 3mm grid sizes which also affect the IMRT QA passing results. Similarly for pelvis cases as like Head and Neck cases.

For Brain cases the p value indicated is less, that it has no significant statistical influence when we plan with 3mm or 5mm. This means that the PTV volume and OAR involved for IMRT planning is less compared to other sites. So, this does not much affect the planning as well as IMRT QA passing results. Even though we did not use many patients for our study, some information we can infer form the data and results obtain. If we use many more patients and compare with p values, we may come to more precise idea.

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