IMRT PATIENT SPECIFIC QUALITY ASSURANCE USING PORTAL DOSIMETRY, IMATRIXX 2-D ARRAY SYSTEM AND COMPASS 3-D VERIFICATION SYSTEM - AN OPTIMIZATION AND DOSIMETRIC STUDY

*a thesis submitted by*

JAYESH. K (08 ZF 010)

*in partial fulfillment for the award of the degree of*

DOCTOR OF PHILOSOPHY

*under the supervision of*

Dr. THARMARNADAR GANESH

*and the joint supervision of*

Dr. SUGANTHI DEVADASON

DEPARTMENT OF PHYSICS

KARUNYA UNIVERSITY

(Karunya Institute of Technology & Sciences)
(Declared as Deemed-to-be-under Sec-3 of the UGC Act, 1956)
Karunya Nagar, Coimbatore – 641 114. INDIA

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DECLARATION

I, JAYESH. K hereby declare that the thesis, entitled “IMRT patient specific quality assurance using portal dosimetry, ImatriXX 2-D array system and Compass 3-D verification system - an optimization and dosimetric study”, submitted to the Karunya University, in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Physics is a record of original and independent research work done by me during the period 2009-2013, under the supervision and guidance of Dr. Tharmarnadar Ganesh, Senior Medical Physicist, Department of Radiation Oncology, King Fahad Specialist Hospital, Dammam, Saudi Arabia and under the joint supervision of Dr. Suganthi Devadason, Professor and Head, Department of Physics, Karunya University. The work contained in this thesis has not been previously submitted to meet the requirements for a degree or diploma at this or any other higher education institution.

Jayesh. K
BONAFIDE CERTIFICATE

Certified that this Thesis titled "IMRT patient specific quality assurance using portal dosimetry, ImatriXX 2-D array system and Compass 3-D verification system - an optimization and dosimetric study" is the bonafide work of JAYESH. K, who carried out the research under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other scholar.

Dr. Suganthi Devadason
JOINT SUPERVISOR

Dr. Tharmarnadhar Ganesh
SUPERVISOR

Dr. S. Vasanth Kumar
Director
School of Science and Humanities
Karunya University
Coimbatore, India
ABSTRACT

Recent technological advances in radiation oncology have led to many advanced treatment techniques like intensity modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT). Although these advances meant substantial benefits for the patient community, a side effect of these developments is that they have also introduced new sources of error that make radiation treatment more vulnerable to treatment delivery errors. As a result, the role of pre-treatment patient-specific quality assurance (QA) in ensuring the quality of treatment and safety of patients has become more important than ever. This research work presents the efforts to improve the process of pre-treatment patient-specific QA. The pass-fail criteria for such patient-specific QA and action levels are based on the general guidelines without having a local institutional optimization strategy based on the available resources, treatment planning and delivery techniques. This research work was performed to explore and establish correlation, if any, between gamma passing rates and the treatment machine’s mechanical and output stability, characteristics of detectors or measurement tools, type of treatment plan, complexity of the plan, number of treatment fields or arcs, treatment site, movement of multileaf collimator (MLC) carriage, mode of treatment delivery, inclusion or exclusion of couch in the treatment plan.

In the first step, assessment of beam stability of linear accelerator was carried out for a period of two years and the quantification of MLC positional errors using
ionometric gravity test and dynalog file analysis was carried out for a period of one year. Along with this output stability of static as well as dynamic MLC fields were also assessed. The test results showed that daily measurements such as flatness, symmetry, beam quality factor and beam output showed good stability, with the values lying well within the tolerance level of < 3% throughout the study period. Consistency in the output of static and dynamic MLC fields were also observed throughout the study period. MLC positional errors were also well within limits specified in the published reports.

The performance characteristics of an aSi1000 electronic portal imaging device (Varian Medical System, Palo Alto, USA) and ImatriXX 2-D array system (IBA Dosimetry, Gmbh, Germany) for patient specific QA measurements were studied and base line values were established. Dependence on source to detector distance (SDD), temperature, field size, dose rate, short term stability and dose linearity were studied and compared with ion chamber measurements. Both aSi1000 EPID and ImatriXX 2-D array system were validated for IMRT and VMAT patient specific QA measurements. As a continuation of the basic characteristics studies, the angular response characteristics of aSi1000 EPID and ImatriXX 2-D array system were also evaluated. Profiles and outputs were measured at gantry angle increments of 10 degrees for a 10x10 cm² field. Flatness, symmetry and output values were compared with those for the reference 0 degree gantry angle measurements. Both systems showed consistency in output. Flatness and symmetry values for profiles did not exhibit any gantry angle dependence and so was the
output. For ten dynamic IMRT plans (total of 65 fields), patient specific QA tests were performed using both detectors. Two sets of measurements were done (i) with all gantry angles reset to Zero and (ii) with true gantry angles as in the treatment plan. From the gamma evaluation of patient specific plans, P-values in student’s t-test for true gantry angles vs. zero gantry angles (portal dosimetry and ImatriXX system) were more than 0.05, indicating no significant variation in gamma value due to angular changes.

In an effort to optimize IMRT and VMAT patient specific QA processes, several measurements were performed for the two techniques with different systems and different geometries. For the IMRT, patient QA measurements were carried for 50 dynamic IMRT cases using portal dosimetry, ImatriXX 2-D array system and point dose measurements. In case of VMAT, QA measurements were performed for 30 cases using point dose measurements and ImatriXX 2-D array system. Planar dose comparison was performed for two different gamma criteria (% dose difference and distance to agreement [DTA]) of 3%-3 mm and 2%-2 mm. At the relatively liberal gamma criteria of 3%-3 mm, the two QA systems (portal dosimetry system and ImatriXX 2-D array system) did not exhibit any obvious difference. However at the tighter criteria of 2%-2 mm, differences in the results were seen. The influence of different factors such as types of plans (IMRT vs. VMAT), complexity (simple pelvic vs. complex head and neck), number of targets (simultaneous integrated boost [SIB] vs. non-simultaneous integrated boost [non-SIB]), number of fields (5 field vs. 7 field and 5 field vs. 9 field) or arcs (single arc
vs. double arc), movement of carriage (split IMRT plans vs. non-split IMRT plans),
inclusion or exclusion of couch in the plan on the gamma results were also analyzed. All these comparisons showed significant variations in student’s t-test. The results demonstrated that for QA optimization, all these individual factors should be taken into account.

As a part of the optimization of patient specific QA process, the TPS-calculated field fluence was sent to a Compass system (IBA Dosimetry, Gmbh, Germany) which then calculated the dose distribution using its own algorithm (collapsed cone). In the dose-volume histogram comparison of ten head and neck and ten pelvic-abdominal IMRT cases, the average dose differences were less than 1% and the average gamma was less than 0.5 for the targets and critical structures. The correlation coefficients for mean and maximum doses were more than 0.8 for complex head and neck cases and more than 0.9 for simple pelvic-abdominal cases. An independent system like Compass can serve as a redundant dose verification mechanism for improving the QA standard in an institution and bring in confidence in treatment delivery using advanced techniques.

This research work showed that an institution-specific effective optimization procedure can be developed for IMRT and VMAT patient specific QA making optimal utilization of available resources. This study has proved that in clinical scenario tighter tolerance criteria can be adopted in suitable situations and the liberal criteria be reserved for plans involving complex situations, a result that can be useful in the implementation of newer treatment techniques.
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JAYESH. K