Dosimetric aspects of a-Si based EPID and its application in advance radiotherapy

This thesis is submitted as a partial fulfillment of the Ph.D. programme in Physics

by:

Kanan Jassal

2008RPH105

Department of Physics

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY, JAIPUR

December, 2014

- To my loving parents, husband, family and friends, thank you for helping me in accomplishing my dreams.
- To my Professors, thank you for your valuable guidance and support.

SUPERVISOR'S CERTIFICATE

This is to certify that the thesis entitled "**Dosimetric aspects of a-Si EPID and its application in advanced radiotherapy**" describes the original research work carried out by **Ms. Kanan Jassal** (ID No. 2008RPH105) for the award of the degree of Doctor of Philosophy (Physics) in Malaviya National Institute of Technology Jaipur (India). This work was done by her during the period July 2008 to December 2014 under our supervision.

Dr. K. Sachdev
(Supervisor)
Associate Professor
Department of Physics
MNIT Jaipur (India)

Dr. A. Chougule
(Co-supervisor)
Professor
Department of Radiological Physics
SMS Medical College and Hospital,
Jaipur (India)

DECLARATION

I herewith declare that I have produced this thesis without the prohibited assistance of third parties and without making use of aids other than those specified; notions taken over directly or indirectly from other sources have been identified as such. This thesis has not previously been presented in identical or similar form to any other Indian or foreign examination board.

The thesis work was conducted from July 2008 to December 2014, under the supervision of Dr. K. Sachdev and Prof. A. Chougule at Department of Physics, Malaviya National Institute of technology, Jaipur and Fortis Memorial Research Institute, Gurgaon.

(Kanan Jassal)

ACKNOWLEDGEMENTS

The accomplishment of this work is credited to the extensive support and assistance received from a number of people. I wish to express my honest and sincere gratitude to my supervisors, Dr. K. Sachdev and Prof. A. Chougule, for their valuable guidance and immense encouragement all the way through my work. Under their direction, I have been strengthened greatly for the activities involved during my research work. I feel extremely privileged to work with them. I appreciate the amount of time and energy that they have put into reading my thesis chapters and manuscripts. My sincere thanks go to Dr. T. Ganesh, who helped me since the day I started writing my thesis. I feel myself fortunate enough to have discussions with him on various aspects of a-Si EPID. I deeply appreciate his teachings and good advices. I am very grateful to Dr. William Joe and Shalini Rudra for their constructive comments on the manuscripts. Dr. T. Kataria and her team have always been willing to help me and provided me with very useful suggestions for my research project.

In addition, I wish to thank, Dr. B. K.Mohanti for numerous valuable discussions and the members of Department of Radiation Oncology at Fortis Memorial Research Institute, Gurgaon—in particular Dr. A.Munshi, Dr. T. Ganesh, Biplab Sarkar, Jeen S. P. Sathiya and S. Krishnankutty- for facilitating and assisting with the data collection and clinical research undertaken in this work. Finally, I would like to thank the faculty, staff and students at the Department of Physics at Malaviya National Institute of Technology, Jaipur for their immense support and help. I am extremely thankful to Prof. S. K. Sharma, Head of the Department for allowing me to use the facilities in the Department. I would also like to express my sincere gratitude to fellow research scholars Parul Gupta, Vikas Sharma, Satyavir Singh and Dinesh Saini. My special appreciation goes to Rishi Vyas for his constant support all the way through this work. I am also thankful to Ms. Deepshikha Desawar, Mr. B. N. Banerjee, Mrs. Prakash Banerjee and Mr. Harinder Singh for helping in completion of my thesis work at Jaipur.

My deepest appreciation goes to my dear husband Nitin, parents and family members. They have supported me always and had been especially endless source of energy while pursuing the research work. I am extremely thankful for their understanding and sacrifices, and for fully encouraging me to pursue my goals in life.

(Kanan Jassal)

ABSTRACT

Geometric and dosimetric errors either individually or together are responsible for compromise in the quality of radiation treatment. The quality assurance/quality control processes account for the reduction of these types of errors in the treatment delivery. The primary step is to extend the comprehensive quality assurance (QA) program to assess mechanical, geometrical, and radiological accuracy desired in the installation and commissioning of the device for the advanced radiotherapy. These processes are performed as a part of the acceptance and commissioning testing of the system. Also, after achieving the suitable results in the initial testing, it is necessary to perform the clinical validation and applicability for the developed system.

The experiments in this work signify the development towards practical and dosimetric applications of a-Si EPID for modern radiotherapy techniques. The dosimetric properties of iViewGT for Elekta Synergy and Axesse linear accelerators were determined for dose, dose rate, field sizes and ghosting effect. The short and long term reproducibility of the developed model was also determined. Also, the possibility of its utilization for the dosimetry of s-IMRT, d-IMRT and VMAT was explored for 250 patients. The implementation of dose measurements using the developed and well correlated model was presented. The overall results of patient-specific QA for these advanced techniques using ion chamber array and a-Si EPID were observed to be comparable to each other. Both portal imager and array were advanced tools for pre-treatment plan quality verification. The study presents the largest reported series for evaluation of treatment plan quality assurance involving all three different delivery techniques with similar equipments performing with similar confidence level.

The modern concept of statistical process control (SPC) was applied for exploring the stability and variations in the process of pre-treatment of 250 patient specific plans. Also, the statistical reliability of the detectors was evaluated using capability (C_{pm}) index. This combination of analysis for treatment plans with the detector reliability parameter provides an effective and synchronized quality control for the equipment and their performance. Comparative results demonstrated that both a-Si EPID and array exhibited consistent and high quality performance for modern radiotherapy dosimetry. Thus, Statistical Process Control has proved to be a quicker and relatively easier method for performing consistency analysis using C_{pm} index.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

µGy	:	micro-Gray
2D	:	Two Dimensional
3D	:	Three Dimensional
AAA	:	Anisotropic Analytic Algorithm
AMFPI	:	Active Matrix Flat Panel Imager
ANOVA	:	Analysis of Variance
AP	:	Anterio-posterior
a-Si EPID	:	Amorphous Silicon Electronic Portal Imaging Device
BB	:	Breast Board
BCS	:	Breast Conservative Surgery
BEV	:	Beam's Eye View
CC	:	Collapsed Cone
C-C	:	Cranio-Caudal
CL	:	Central Line
CNR	:	Contrast to Noise Ratio
COL	:	Coefficient of Linearity
CR	:	Computerized Radiography
CRT	:	Conformal Radiotherapy
CT	:	Computed Tomography
d-IMRT	:	Dynamic Intensity Modulated Radiotherapy
$D_{0.125cc}$	:	Dose as Measured by the 0.125cc Semi-Flex Ionization Chamber
DD	:	Dose Difference
d-IMRT	:	Dynamic Intensity Modulated Radiotherapy
D_{mean}	:	Mean organ dose
D_p	:	Prescription Radiation Dose
DQE	:	Detection Quantum Efficiency
DRR	:	Digitally Reconstructed Radiograph
DTA	:	Distance-to-agreement
D_{tps}	:	Dose as Calculated by the Treatment Planning System
DVH	:	Dose Volume Histogram

EC-L	:	Enhanced Contrast Localization
EWMA	:	Exponentially Weighted Moving Averages
GTV	:	Gross Tumor Volume
HVL	:	Half Value Layer
ICRU	:	International Commission on Radiation Unit
IGRT	:	Image Guided Radiation Therapy
IMAT	:	Intensity Modulated Arc Therapy
IMRT	:	Intensity Modulated Radiation Therapy
JB	:	Jarque-Bera
kV	:	kilo-voltage
kV_p	:	Peak kilo-volatge
LCL	:	Lower Control Limit
LED	:	Lateral Electronic Disequilibrium
Linacs	:	Linear Accelerator
mAs	:	milli-Ampere Seconds
ML	:	Medio-Lateral
MLC	:	Multi Leaf Collimator
MV	:	Mega Voltage
NKI	:	NederlandsKankerInstituut
NTCP	:	Normal Tissue Complication Probability
OAR	:	Organs-at-risk
PTV	:	Planning Target Volume
QA	:	Quality Assurance
QC	:	Quality Control
R	:	Roentgen
Ra	:	Radium
RMS	:	Root Mean Square
ROI	:	Regions of Interest
RTP	:	Radiation Treatment Planning
SDD	:	Source to Detector Distance
SIB	:	Simultaneous Integrated Boost
s-IMRT	:	Static/step-and-shoot/segmental/sequential Intensity Modulated Radiotherapy
SLIC	:	Scanning Liquid Filled Ion Chamber

SNR	:	Signal to Noise Ratio
SPC	:	Statistical Process Control
SWO	:	Segment Weight Optimization
TCP	:	Tumor Control Probability
TFT	:	Thin Film Transistor
TQM	:	Total Quality Management
UCL	:	Upper Control Limit
V_{10Gy}	:	Volume of the organ receiving 10 Gy
V_{20Gy}	:	Volume of the organ receiving 20 Gy
V_{25Gy}	:	Volume of the organ receiving 25 Gy
V_{30Gy}	:	Volume of the organ receiving 30 Gy
V_{5Gy}	:	Volume of the organ receiving 5 Gy
VC	:	Vacuum Cushion
VEF	:	Virtual Energy Fluence
VMAT	:	Volumetric Modulated Arc Therapy
W-L pointer	:	Winston-Lutz pointer
XVMC	:	X-ray Virtual Monte-Carlo