INVESTIGATION OF A MODIFIED ELECTRONIC PORTAL IMAGING DEVICE FOR IMPROVING DOSIMETRY IN RADIOTHERAPY

Mahsheed Sabet

BSc, MSc

A thesis submitted for the degree of
Doctor of Philosophy (Physics) from the
Faculty of Science and Information Technology,
University of Newcastle

JANUARY 2012

DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying subject to the provisions of the Copyright Act 1968.

Mahsheed Sabet

ACKNOWLEDGEMENT OF AUTHORSHIP

I hereby certify that the work embodied in this thesis has been done in collaboration with other researchers. I have included as part of the thesis a statement clearly outlining the extent of collaboration, with whom and under what auspices.

Mahsheed Sabet

ACKNOWLEDGEMENTS

The start of this thesis was the beginning of a major change to my life. It was an amazing journey and I have enjoyed every moment of it. Now the time has come to sincerely thank those who have helped me complete this project.

First I should thank the Australian Federal Government and the University of Newcastle for awarding generous scholarships that gave me the opportunity for this excellent learning experience.

I am truly grateful to Associate Professor Peter Greer for his scientific expertise, guidance, critical thinking and friendliness throughout the last three years. He not only provided the original idea around which this thesis was based, but also taught me how to think about the problem and gave me the confidence to set my goals high. And above all this, he practically taught me with his unique personality to remain calm in difficult conditions. I have learnt so much from you Peter and can never thank you enough for all you have done.

I would also like to express deepest gratitude to my co-supervisor Professor Fred Menk for his invaluable help and guidance throughout this project. Thank you so much Fred for your mindfulness and superb suggestions and for your concerns about my future, despite your important responsibilities at the university.

I have had the pleasure of working with some other fine physicists: Assistant Professor Boyd McCurdy and Dr. Eric Van Uytven from Cancercare Manitoba, Canada; Associate Professor Zdenka Kuncic from the University of Sydney; Associate Professor Martin Ebert from the University of Western Australia; Dr. Kym Nytschke chief physicist at Calvary Mater Newcastle hospital; Dr. Phillip Vial from Liverpool Hospital; and Dr. Tanya Kairn from Premion Radiotherapy Services in Queensland. I would like to thank them all for their useful advice and thank Peter again for providing the contacts to these wonderful scientists. Professor Jeffrey Siebers from Virginia Commonwealth University is gratefully acknowledged for providing the data on the EPID structure.

I would also like to say a warm thank you to my dear friends in the radiation oncology department at Calvary Mater Newcastle hospital:

Kristie Harrison, Ekta Jhala, Tamara Molloy and Bruce Aldrich, you have always been so nice and caring and were always there when I needed help. You are so special to me and I'll never forget your kindness and support.

Dennis Pomare, Karl Stansfield and Chris Lewis in the electronics group who were always ready to help when there was a problem on the machines, even on hot summer weekends. You patiently taught me some of the secrets of linacs. Thank you.

Ray Sheather and Hetal Shah in the IT group: The project could not have been finished without you being there all the time with helping hands, fixing the never-ending issues with the computer systems. Thank you both.

And thank you all friendly staff at the department of radiation oncology who shared the equipment with me with smiling faces.

I have also had the pleasure of sharing the office with Mrs. Joan Hatton, Dr. Brian King and Todsaporn Fuangrod for more than two years. Thank you Joan for all your kind considerations and your true friendship. Thanks Brian for trying to help with that annoying C program, and thanks O for bringing happiness to the office.

And finally Pejman who helped me in every step of the work and stayed with me during the long hours of measurements and offered his full support all the time, thank you for all you have done for me and for your unconditional love.

TABLE OF CONTENTS

ABSTRACT

In modern radiotherapy treatments such as Intensity Modulated Radiation Therapy (IMRT), megavoltage beams are delivered using plans that usually include sharp dose gradients. Therefore, high resolution dosimetry devices which provide accurate two-dimensional data are required to ensure the correct delivery of radiation fields. There has been growing interest on using Electronic portal imaging devices (EPIDs) for dosimetry applications. A major problem associated with amorphous silicon (a-Si) EPIDs for transit dosimetry is the presence of a phosphor layer, which can introduce large deviations from water-equivalent behaviour due to energy-dependent response and visible light scattering.

In the present study, the phosphor scintillator screen and all other layers above it were removed from the structure of a research-dedicated a-Si EPID and were replaced by buildup layers. The modified EPID (to direct detection configuration) was evaluated for dosimetry applications by comparison to ionization chamber in water measurements for 6 and 18 MV treatment beams. The indirect (unmodified) EPID was similarly investigated in transit dosimetry conditions for comparison. The direct EPID with 3 cm solid water buildup showed water-equivalent response in all tested conditions except for very thick phantoms in 6 MV beams which could be easily corrected, while the indirect EPID was sensitive to changes in field size, phantom thickness and off-axis distance. Some of the EPID characteristics which could affect dosimetry measurements (such as dose rate dependence and image lag) were also investigated for both EPID configurations.

The direct EPID was tested for absolute dosimetry measurements with slab and anthropomorphic phantoms in a number of clinical IMRT fields by comparison to a two dimensional array of ionization chambers used as reference and the Gamma evaluation (3%, 3 mm criteria) showed that on average 97.9% of points had a Gamma index less than 1.

Monte Carlo method was used to simulate the head of a linear accelerator for 6 MV beams (using BEAMnrc) and the direct EPID (using DOSXYZnrc). The models were then used to simulate the same transit dosimetry conditions as used for the measurements. The agreement of the relative measured and simulated image profiles on the central axis were within 3% for square fields with slab phantoms in the beam. For a

head and neck phantom in a dynamic IMRT beam, the Gamma evaluation of measured and simulated relative dose images showed 80.3% of points with Gamma index less than 1 (3%, 3 mm criteria).

A simple measurement-based correction model was also developed to correct the EPID images and use them for water-equivalent transit dosimetry without the application of any kernels. The model was tested by comparison of the absolute dose images measured by the EPID and a reference two dimensional array of ionization chambers for clinical IMRT fields in transit conditions, and as a result on average 99.5% of points had a Gamma index less than 1 (3%, 3 mm criteria).

The only drawback of using the EPID in direct configuration is the poor quality of images compared with the indirect EPID. If direct EPIDs are used as two-dimensional dosimeters mounted on linacs, on-board kilovoltage imaging devices could be used as an alternative for the EPID (as imager) to confirm patient positioning.

LIST OF ABBREVIATIONS

AMFPI	Active Matrix Flat Panel Imager
a-Si	amorphous silicon
CCD	Charge Coupled Device
d_{max}	depth of maximum dose
dEPID	direct Electronic Portal Imaging Device
DF	Dark Field
EPID	Electronic Portal Imaging Device
FF	Flood Field
FWHM	Full Width at Half Maximum
iEPID	indirect Electronic Portal Imaging Device
Linac	Linear accelerator
MLC	Multi-Leaf Collimator
MU	Monitor Unit
OAR	Off Axis Ratio
SDD	Source to Detector Distance
SLIC EPID	Scanning Liquid-Filled Ionization Chamber EPID
TLD	Thermo-Luminescent Dosimeter
TMR	Tissue Maximum Ratio
VEPID	Video based EPID