Improvement of EPID-based techniques for dosimetry and investigation of linac mechanical performance in advanced radiotherapy

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

July 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.

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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.

(Signed) ____________________

ACKNOWLEDGEMENTS

I would like to express my deepest and most sincere gratitude to my supervisors, Associate Professor Peter Greer and Professor John O'Connor for their guidance, full support, constructive and valuable comments, and continuous encouragement throughout this project.

I wish to thank the University of Newcastle and the Department of Radiation Oncology at Calvary Mater Newcastle Hospital for providing the much needed scientific environment and resources during the past three years. The generous scholarship offered by the University of Newcastle is gratefully appreciated.

I had the pleasure of having a regular series of interesting discussions with our friends in the medical physics research group at the University of Manitoba, Canada. I would like to thank them all, especially Assistant Professor Boyd McCurdy and Peter McCowan who collaborated in parts of this project.

The wonderful engineers in the electronics group of Calvary Mater Newcastle, Dennis Pomare, Christopher Lewis, and Karl Stansfield always provided me with good advice with their remarkable expertise. I also had useful and interesting discussions with Dr Kym Nitschke, Dr Patricia Ostwald and Michael Barnes from the physics group. I hereby thank all of them for their help and assistance.

The anonymous reviewers and editors of my papers who provided helpful suggestions and indirectly improved the quality of this work are gratefully acknowledged.

I enjoyed sharing the office with Todsaporn Fuangrod during the past two years. He brought a fresh taste of engineering to the office, in addition to the amazing taste of home-cooked Thai food. Thank you mate for your friendship.

And my loving thanks go to my wife Mahsheed who patiently helped me in extensive measurement series and contributed in preparing the articles in spite of doing her own PhD. Without her support and encouragement, it would have been impossible to finish this work.

LIST OF PUBLICATIONS INCLUDED AS PART OF THE THESIS

Peer reviewed journal publications:

1. Rowshanfarzad P, McCurdy BMC, Sabet M, Lee C, O'Connor DJ, Greer PB. Measurement and modeling of the effect of support arm backscatter on dosimetry with a Varian EPID, *Medical Physics*, 2010; 37(5): 2269-2278.

2. Rowshanfarzad P, Sabet M, O'Connor DJ, Greer PB. Reduction of the effect of non-uniform support-arm backscatter for dosimetry with a Varian a-Si EPID, *Physics in Medicine and Biology,* 2010; 55: 6617-6632.

3. Rowshanfarzad P, Sabet M, O'Connor DJ, Greer PB. Improvement of Varian a-Si EPID dosimetry measurements using a lead-shielded support-arm, *Medical Dosimetry*, 2012; 37(2): 145-151.

4. Rowshanfarzad P, Sabet M, O'Connor DJ, Greer PB. Impact of the backscattered radiation from the bunker structure on EPID dosimetry. *Journal of Applied Clinical Medical Physics*, 2012; 13(6): 91-100.

5. Rowshanfarzad P, Sabet M, O'Connor DJ, Greer PB. Verification of the linac isocentre for stereotactic radiosurgery using cine-EPID imaging and arc delivery, *Medical Physics*, 2011; 38(7): 3963-3970.

6. Rowshanfarzad P, Sabet M, O'Connor DJ, Greer PB. Isocentre verification for linac-based stereotactic radiation therapy: *review* of principles and techniques, *Journal of Applied Clinical Medical Physics*, 2011, 12(4): 185-195.

7. Rowshanfarzad P, Sabet M, O'Connor DJ, McCowan PM, McCurdy BMC, Greer PB. Detection and correction for EPID and gantry sag during arc delivery using cine EPID imaging, *Medical Physics*, 2012; 39(2): 623-635.

8. Rowshanfarzad P, Sabet M, O'Connor DJ, Greer PB. Investigation of the sag in linac secondary collimator and MLC carriage during arc deliveries, *Physics in Medicine and Biology,* 2012; 57(12): N209-224*.*

9. Rowshanfarzad P, Sabet M, O'Connor DJ, McCowan PM, McCurdy BMC, Greer PB. Gantry angle determination during arc-IMRT: Evaluation of a simple EPID-based technique and two commercial inclinometers. *Journal of Applied Clinical Medical Physics*, 2012; 13(6): 203-214.

10. Rowshanfarzad P, Sabet M, Barnes MP, O'Connor DJ, McCurdy BMC, Greer PB. EPID-based verification of the MLC performance for dynamic IMRT and VMAT. *Medical Physics*, 2012; 39(10): 6192-6206.

LIST OF ADDITIONAL PUBLICATIONS

Peer reviewed abstracts:

1- Rowshanfarzad P, Sabet M, McCowan PM, McCurdy BMC, O'Connor DJ, Greer P. A New Method for Linear Accelerator Characterization for VMAT Using Cine-EPID. *Medical Physics*, 2011; 38(6): 3726 (proceedings of the 2011 Joint AAPM/COMP Meeting, 31 July-04 August 2011, Vancouver, Canada).

2- McCowan P, Rickey D, Rowshanfarzad P, Ansbacher W, Greer P, McCurdy B. Precise Gantry Angle Determination for EPID Images during Rotational IMRT. *Medical Physics*, 2011; 38(6): 3534 (proceedings of the 2011 Joint AAPM/COMP Meeting, 31 July-04 August 2011, Vancouver, Canada).

3- Rowshanfarzad P, Sabet M, O'Connor DJ, Greer P. Comprehensive verification of the linac isocentre for stereotactic radiosurgery using cine-EPID and arc delivery. *Radiotherapy & Oncology*, 2011; 99 (Suppl 1): S 566-7 (Proceedings of the 11th BIENNIAL ESTRO Conference on physics and radiation technology for clinical radiotherapy, London, UK, 8-12 Aug 2011).

4- Sabet M, Rowshanfarzad P, King B, Menk F, Greer P. Comparison of the image lag for an aS500 EPID in direct and standard clinical configurations. *Australasian Physical & Engineering Sciences in Medicine*, 2011; 34: 160 (Proceedings of Engineering and Physical Sciences in Medicine (EPSM), Melbourne, Australia, 5-9 Dec 2010).

5- Rowshanfarzad P, Sabet M, McCurdy BMC, McCowan PM, O'Connor DJ, Greer PB. Investigation of the gantry and EPID sag during arc therapy for a Varian Trilogy linac, *Australasian Physical & Engineering Sciences in Medicine*, 2011; 34: 160 (Proceedings of Engineering and Physical Sciences in Medicine (EPSM), Melbourne, Australia, 5-9 Dec 2010).

6- Rowshanfarzad P, Sabet M, O'Connor DJ, Greer PB. Amelioration of the effect of non-uniform arm backscatter on dosimetry with a Varian a-Si EPID. *Medical Physics*, 2010; 37(7): 3911 (proceedings of the 56th annual meeting of the Canadian organization of medical physicists and the Canadian college of physicists in medicine, 15-19 June 2010, Ottawa, Canada).

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8- Rowshanfarzad P, Sabet M, McCurdy BMC, O'Connor DJ, Greer PB. A measurement-based model for backscatter from an a-Si EPID support arm to improve IMRT dose verification, *Journal of Medical Imaging and Radiation Oncology,* 2009; 53(Suppl. 1): A174. (Proceedings of RANZCR/AIR/FRO/ACPSEM Combined Scientific Meeting, 22-25 Oct. 2009, Brisbane, Australia).

9- Rowshan-Farzad P, Sabet M, McCurdy B, Greer P. A model of EPID support arm backscatter for improved IMRT and Arc-IMRT verification with EPID. *Radiotherapy & Oncology*, 2009; 92(Suppl 1): S24-5 (Proceedings of the 10th BIENNIAL ESTRO Conference on physics and radiation technology for clinical radiotherapy, Maastricht, The Netherlands, 30Aug to 3Sep 2009).

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11- Sabet M, Rowshanfarzad P, Menk F, Greer P. A simple correction method for EPID transit dosimetry measurements. 12th International Conference on Electronic Patient Imaging (EPI2k12), 12-14 March 2012, Sydney, Australia.

12- McCowan PM, Rickey DW, Rowshanfarzad P, Greer PB, McCurdy BMC. IMAT Gantry Angle Correction for Cine-Mode EPID Images. 12th International Conference on Electronic Patient Imaging (EPI2k12), 12-14 March 2012, Sydney, Australia.

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ABSTRACT

Advances in radiotherapy have increased the complexity of treatment delivery techniques. The complexity of plans, with dynamic variation of field shape, gantry speed and dose rate require highly accurate techniques for quality assurance of the treatment machines and dosimetric verification of the treatment plans.

There has been a growing interest on the application of electronic portal imaging devices (EPIDs) for dosimetry applications and quality assurance testing of linear accelerators (linacs). The ultimate aim of this thesis is to develop methods to ensure more accurate treatment deliveries using EPID-based techniques.

The project is divided into two parts. The first part is based on improvement of the accuracy of EPID dosimetry with Varian systems by either accounting for, or reduction of, the effect of backscattered radiation from the treatment room walls and the EPID support arm.

The effect of backscatter from the treatment room walls was quantified for the first time using a number of measurement setups and comparisons with measurements in the presence of an independent portable wall. The Varian support arm backscatter was accounted for or reduced by three methods: (a) application of an experimentally derived backscatter kernel into an existing EPID dose prediction model, (b) insertion of lead sheets to reduce the non-uniform backscatter, and (c) insertion of a thicker piece of lead over the arm area and considering it as an arm component which could effectively reduce the backscatter effect. Application of the backscatter kernel measured with this lead shielded arm into the model was the most effective method to improve the accuracy of EPID dosimetry predictions.

In the second part of the project, EPID-based measurement methods were used and new algorithms were developed for faster, easier, more robust, more accurate quantitative techniques for characterization of the linac components than existing methods. The results could be used for improvement of EPID dosimetry measurements and/or be included in the linac quality assurance program. The study includes: determination of the mechanical isocentre position with a level of accuracy suitable for stereotactic treatments; determination of the sag in EPID, gantry, jaws and MLC systems during arc deliveries; determination of gantry angle during rotation; and finally, a comprehensive investigation of MLC leaf positioning and dynamic performance in static and arc delivery modes.

The proposed methods have been tested and are applicable for routine quality assurance of the linear accelerators used for advanced treatment techniques with all linacs, independent of their make and model.