Ain Shams University
Faculty of women for Arts, Science and Education

Assessment the Factors Affecting on Skin Dose in Photon Beam Radiotherapy

By

Yasser Hassan Ali Hassanein

B.Sc. in Biophysics, Cairo - University

A thesis submitted in conformity with the requirement for M.Sc. in Science (Physics - Biophysics), Faculty of women for Arts, Science and Education.

SUPERVISORS

Prof. Dr. Hosnia M. Abu-Zeid
Prof. of Nuclear Physics
Phys. Dept., Women Faculty for Arts, Sci., and Education,
Ain -Shams University.

Prof. Dr. Hoda A. Ashry
Prof. of Radiation Physics
National Center for Radiation Research and Technology,
Atomic Energy Authority.

Dr. Khaled Mohamed El Shahat
Ass. Prof. of Medical Radiation Biophysics,
Faculty of Medicine,
Al - Azhar University

2013

Supervision Committee
Approval Sheet

Assessment the Factors Affecting on Skin Dose in Photon Beam Radiotherapy

Presented by

Yasser Hassan Ali Hassanein

Submitted for partial fulfillment of M.Sc. Degree in Science (Physics - Biophysics), Faculty of women for Arts, Science and Education.

Approved by:	***signature***
Prof. Dr. Hosnia M. Abu-Zeid **Prof. of Nuclear Physics** **Phys. Dept., Women Faculty for Arts, Sci., and Education, Ain - Shams University.**	
Prof. Dr. Hoda A. Ashry **Prof. of Radiation Physics** **National Center for Radiation Research and Technology, Atomic Energy Authority.**	
Dr. Khaled Mohamed El Shahat **Ass. Prof. of Medical Radiation Biophysics,** **Faculty of Medicine,** **Al-Azhar University**	

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قُلْ لَوْ كَانَ الْبَحْرُ مِدَادًا لِكَلِمَاتِ رَبِّي لَنَفِدَ الْبَحْرُ قَبْلَ
أَنْ تَنْفَدَ كَلِمَاتُ رَبِّي وَلَوْ جِئْنَا بِمِثْلِهِ مَدَدًا ﴿١٠٩﴾
قُلْ إِنَّمَا أَنَا بَشَرٌ مِثْلُكُمْ يُوحَى إِلَيَّ أَنَّمَا إِلَهُكُمْ
إِلَهٌ وَاحِدٌ فَمَنْ كَانَ يَرْجُو لِقَاءَ رَبِّهِ فَلْيَعْمَلْ عَمَلًا
صَالِحًا وَلَا يُشْرِكْ بِعِبَادَةِ رَبِّهِ أَحَدًا ﴿١١٠﴾

[سورة الكهف]

Acknowledgements

I am kneeling obsequiousness to ALLAH thanking HIM for showing me the right way. Without God help, my efforts would have gone astray. It was through the grace of God that I was able to acquire this great accomplishment. Thanks also for a person I love him very much, the Prophet Mohammed {God's praise and peace upon}.

Great thanks to the Head of Physics Department for her kind help and continuous encouragement for me and all young scientists in our department.

Also, I wish to express all my deepest and sincerest gratitude to ***Prof. Dr. Hosnia M. Abu-Zeid (Prof. of Nuclear Physics, Physics Depart., Women Faculty for Arts, Science, and Education, Ain - Shams University).*** *I am deeply indebted to her for her enormous patience, guidance, and support throughout the work program. My inspiration came from her passion for research and her confidence in my abilities. Working under her leadership in such an exciting field was both educationally and professionally enriching. As a model researcher, I look up to her for inspiration in my professional career.*

I wish to express my deepest sincerest thanks to ***Prof. Dr. Hoda Abdel-Moniem Ashry (Prof. of Radiation Physics, National Center for Radiation Research and Technology, AEA.).*** *for her capable supervision, guidance that helped enhancing my understanding of this field and who has given me much guidance necessary for this project,* *and done so with a great deal of patience and valuable insight. She has been the driving force of this project.*

I would also like to extend a special thanks to ***Dr. Khaled Mohamed El Shahat (Ass. Prof. of Medical Radiation Biophysics, Physics Depart., Faculty of Medicine, Al - Azhar University),*** *who was more helpful, understanding, and enjoyable to work with throughout the course of the work, and for his capable supervision, fruitful guidance, encouragement, ideas, endless help and many illuminating discussions through the course of the investigation.*

I would also like to thank the Radiation Biophysics Laboratory team, Physics Department, Women Faculty, Ain Shams University for supporting this work.

Finally, but in no way the least important, I would like to thank my family, for their support, encouragement, and understanding throughout my M.Sc.'s research and for all the good and bad times we had together.

Dedicated

To

My parents (Father and Mother),

My wife,

My brothers,

My sisters,

My cognates,

My professors

and

My colleagues

ABSTRACT

Abstract

Gamma and x-rays beams used in radiotherapy are contaminated with secondary electrons. Skin dose has two components depending on secondary electrons produced from photon interactions with air, collimator jaws, the patient surface and any other scattering materials these components are: (1) secondary electrons generated in the patient, and (2) contaminant electrons from the treatment head. It is not possible to change the effect of treatment head materials on skin dose in clinical applications, but skin dose can be changed by using different treatment setup parameters. Therefore, the knowledge of how parameters affect the skin dose is essential for proper treatment.

Many authors have assessed dose in the surface and buildup region for normally incident photons and there are a number of articles in the literature concerning surface dose and buildup at open fields, source to surface distances, oblique angles (gantry angles), various blocks tray, filters, and wedge angles. The aim of the present work is assessment the dose distribution in buildup regions generated by our beams with different treatment setup parameters, applying the Eclipse TPS to calculate the dose distribution correctly in buildup regions, and drawing a model able to predict the skin dose with precision of about +/- 5.0 % for the most treatment conditions available applying both treatment units (cobalt (T780E) and linear accelerator). A 'Markus' parallel plate PP chamber was used for these measurements in both cobalt (T780E) and Varian (6.0 MV -15 MV) linear accelerator. Cobalt beam build-up zones were very poorly described by the conventional beam data acquisition procedures and they are usually flatter than those produced by higher energy machines. All our measurements were done in the central part of the beam and were assessed for dose at entry surface.

In higher energy photon beams we can expect observing the similar phenomena with deeper build-up zones as the range of electron set in motion will be multiple of that generated by cobalt photons.

Eclipse treatment planning system TPS was tested with respect to skin dose calculation. Calculated data were compared with measurements using both ionization chambers and thermo-luminescent chips.

Skin dose was found being dependent on collimator opening, the measured skin dose showed that skin dose increased as field size increased. As the field size increased the skin dose increased. This increasing is due to increased electron emission from the collimator and air. Measured skin dose values for cobalt were higher than those of 6 MV and 15 MV.As the energy increased, the skin dose decreased with increasing the collimator opening. This decreasing is due to decreasing the linear energy transfer LET.

The results of different source to skin distances SSD with field size for different energies showed the variation in skin dose with SSD. The skin dose increased as SSD decreased while increased as field size increased and increased as energy decreased. The Percentage surface dose is nearly stable with different Source to Skin Distance SSD. The air between source and skin generates secondary electrons and these electrons absorbed or scattered in air depending on beam divergence and some of them can reach the patient's skin.

The results of different Gantry angles GR with different energies showed that with increasing the gantry angles (0 to 30) degree produces a minimal effect of dose and with increasing the gantry angles (40 to 70) degree produce a dominate increase. This increase is monotonic (but nonlinear) with increasing angle. This effect on skin dose is due to that the depth of dose maximum (D_{max}) is shifted toward the shallower depth with increasing the gantry angle.

Insertion of beam modifiers proved to have a less effect on cobalt beam. At least under standard conditions (field size FS = 10x10 cm², source to skin distances SSD = 100 cm) insertion of trays and wedge filters into the cobalt beam does not affect significantly neither surface dose D_{surf} nor the skin dose D_{skin}. But, for 6.0 MV and 15 MV photon beams, the percentage skin doses for open fields were lower than the percentage skin doses fields when adding bolus. This effect on skin dose is due to that the depth of dose maximum (D_{max}) is shifted toward the shallower depth (surface) with increasing bolus thickness toward the depth of equilibrium.

Measurements are taken for the entire range of field sizes available on the linear accelerators (5x5 cm² to 40x40 cm²) with an acrylic blocking tray. Skin dose values with the acrylic block tray were higher than those with the open field. It may be concluded that the effects of the blocking tray on skin dose were quite significant and increased with increasing field size. The tray eliminates the electrons from upstream and generates new secondary electrons by itself. The number of electrons originating at the tray is larger than the number of electrons eliminated by the tray.

The skin dose for a physical wedge PW field increased as field size increased with fixed wedge angle but skin dose value for physical wedge fields lower than those with an open field. The skin dose values for wedge fields increased as field size increased. The skin dose decreased as the wedge angle increased at fixed source to skin distance SSD. Physical wedge PW eliminates secondary electrons but generates new electrons. It may be concluded that the number of electrons produced by the wedge was lower than the number of electrons eliminated by the wedge.

The skin dose measurements at off-axis distance (2.0, 4.0 and 5.0 cm from the central axis) were studied with a 10x10 cm² opened field size. The skin dose decreased as the off-axis distances increased. This effect is dominant at the field edges.

The presented study shows that Eclipse treatment planning system in its currently used version fails to calculate skin dose accurately enough. It assesses the skin dose at the entry surface by a simple approximation of the dose build-up curve regardless the conditions.

The study resulted in a simple calculation procedure that could estimate skin dose in relative units within +/- 5.0 % for the most of treating conditions. The skin dose is then expressed as a fraction of dose calculated either by Eclipse or by other planning system in the nearest point possessing full equilibrium of charged particles.

The assessment of skin dose becomes an important treatment parameter as either the higher skin reaction can put a serious restriction to the radiation treatment or the insufficient surface dose can reduce the tumor control.

Contents

List of Symbols & Abbreviations

List of Figures

List of Tables

List of Published Papers

English Abstract

Page

Chapter 1

Chapter 1 Introduction and Theory……………….……..…………………….....1

1.1 General…………………………………………………..……………...2

1.2. Basic Physics of Radiotherapy……………………..…………………….3

1.3. Interaction properties of x-rays and electrons…..………..…………………....3

1.4. Clinical consideration for photon beams……….…………………………......6

1.4.1. External beam radiation therapy…………....………………………........6

1.4.2. Effect of radiation in cancer treatment………..…….………………………8

1.4.3. Effect of multiple beams…………………………………………………9

1.5. General shape of the depth dose curve……………………………………....11

1.6. Isodose curves……………………………………………………….……13

1.7. Parameters of Isodose Curves …………………………………….…………16

1.7.1. Beam Quality………………………………………………..…....16

1.7.2. Source Size, Source to Surface Distance, and Source to
Diaphragm Distance - the Penumbra Effect……………………..……...16

1.7.3. Collimation and Flattening Filter……………...………………...………..17

1.7.4. Field Size…………………………………………………………………..17

1.8. A Typical radiotherapy course………………………………..……………17

1.8.1. Planning margins……………………………………………………..19

Page

1.8.2. Specification of Target Dose…………………………………………….....21
1.8.3. The ICRU Reference Point…………………………………………...……22
1.8.4. Dose Volume Histograms (DVHs)…………………………... ………...23
1.9. Advantages of Skin………………………………………………..…....25
1.10. Anatomy of the Skin…………………………………………………..25
1.10.1. Epidermis (basal)……… ……………………………………………...25
1.10.2. Dermis……………..………………..……………………………….26
1.10.3. Subcutaneous Tissue…………………………………………………...26
1.11. Side Effects of Radiotherapy…………………………………………....27
1.12. Electron Contamination……………………………………………………28
1.13. Skin Cancer…………………………………………………………...29
1.14. Definition of Skin (Surface) Dose……………...30
1.15. Dosimeters Used for Surface Dose Measurements……...……....................30
1.15.1. Extrapolation Parallel Plate Ionization Chamber………………………...31
1.15.2. Parallel Plate Ionization Chamber……………………………………..31
1.15.3. Thermo-luminescent Dosimeter (TLD)……… …..................................31
1.15.4. Radiographic Films…………………………………………………….32
1.15.5. Radiochromic Films……………………...32
1.15.6. Monte Carlo Simulation………………………………………………..32
1.16. Measurement of Surface Dose with Parallel-Plate Chambers……………...33
1.16.1. Over-Response……… ………………………………………………..33
1.16.2. Polarity Effect………..35
1.17. Corrections for Surface Dose Measurements……………………………….35
1.18. Literature review………...38
1.19. Objective of the Study and Specific Aims……..44

Page

Chapter 2

Chapter 2 Experimental Techniques and Methods……..……………..…....46

2.1. Techniques…………………………………………………………………..47

2.1.1. Medical Cobalt-60 Unit……………..47

2.1.1.1. Description of Cobalt- 60 Machine ……………………………………..48

2.1.2. Medical Linear Accelerator………………………….............................49

2.1.2.1. Head Construction and Collimator System Design……………………...50

2.1.2.2. Treatment Head…………………………………………………………..51

2.1.2.3. Ionization Chambers for Dose Monitoring………………………………....52

2.1.2.4. Fixed and mobile collimators ………………………………………………52

2.1.3. Dosimetric instrumentations…………………………………………………53

2.1.3.1. Ionization Chambers (IC)…………………………………………………54

2.1.3.2. Thermoluminescent Dosimeter…..………………………………………54

2.1.3.3. Solid Phantom…………………………………………………………56

2.1.4. The Eclipse TPS………………………………………………………...57

2.2. Methods of measurements..59

2.2.1. Measurement of surface dose D_{sur} and skin dose D_{skin}…..............................59

2.2.2. Calculation of Surface dose D_{sur} and skin dose D_{skin} values by TPS……....62

Chapter 3

Chapter 3 Results & Discussions…………………………………………………63

3.1. The specific aims of this study ………………..……………………………65

3.2. Results…………………………………………………………………….....66

3.2.1. Effect of different clinical setup parameters…………………......................66

Page

3.2.1.1. Skin Dose with Different Field Sizes FS ………………………………..66
3.2.1.2. Skin Dose with Different Source to Skin Distances SSD………………..72
3.2.1.3. Skin Dose with Different Gantry Angles GR……………………………75
3.2.1.4. Skin Dose with Different Modifiers………………................................77
3.2.1.5. Skin Dose with Different Wedge Angles for (6 MV&15 MV)…… ……83
3.2.1.6. Skin Dose with Different Off-Axis Distances for (6 MV&15 MV)……..88
3.2.2. Applying the Eclipse TPS to calculate the dose distribution correctly in buildup regions…………………..89
3.2.3. Comparison between the Skin Dose Measurements data and Treatment Planning System TPS data………………………………………..……....91
3.2.3.1. Skin Dose on Entry Surface……………………………………….......91
3.2.3.2. Skin Dose at Exit Surface……………………..92
3.2.3.3. Skin Dose at Lateral Surface…………………………………….............93
3.2.4. Design simple model to estimate the skin dose……..……………………..94
3.3. Discussions……………...………………………………………………...102
3.3.1. Skin Dose on Entry Surface……………………………………..............103
3.3.1.1. From Cobalt beam ……………………………….……………………..103

3.3.1.2. From Linear Accelerator (6 MV&15 MV) beam……………………….105
3.3.2. Skin Dose on Lateral and Exit Surfaces……………………………….....110

Chapter 4

Chapter 4 Conclusions…………………………...…………………………..112