INVESTIGATION OF TREATMENT PLANNING AND DOSE VERIFICATION PROCEDURES USING UNFLAT LINAC PHOTON BEAMS

A

THESIS

SUBMITTED TO

MAHARAJA RANJIT SINGH
PUNJAB TECHNICAL UNIVERSITY
BATHINDA, PUNJAB (INDIA)

IN FULFILLMENT OF THE REQUIREMENTS
FORTHE DEGREE OF

DOCTOR OF PHILOSOPHY
IN
FACULTY OF SCIENCES

By
Shekhar Dwivedi
(Registration No.–16406MPE01)
Department of Physics
Maharaja Ranjit Singh Punjab Technical University
Bathinda, Punjab, India
(OCTOBER 2022)

CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the thesis, entitled **"INVESTIGATION OF TREATMENT PLANNING AND DOSE VERIFICATION PROCEDURES USING UNFLAT LINAC PHOTON BEAMS"** in fulfilment of the requirements of the award of the degree of Doctor of Philosophy in Faculty of Sciences and submitted in Department of Physics, Maharaja Ranjit Singh Punjab Technical University, Bathinda, is an authentic record of my own work carried out during a period from August 2016 to October 2022 under the supervision of **Dr. Sandeep Kansal, Professor & Head, Department of Physics, MRSPTU, Bathinda and Dr. Vinod Kumar Dangwal (Co-supervisor), Associate Professor (Medical Physics), Department of Radiotherapy, Government Medical College, Patiala.**

The matter embodied in this thesis has not been submitted by me for the award of any other degree of this or any other University/Institute.

(Shekhar Dwivedi)

Registration No. 16406MPE01

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

(Dr. Sandeep Kansal)
(Supervisor)
Department of Physics
MRSPTU, Bathinda

(Dr. Vinod Kumar Dangwal)
(Co-Supervisor)
Department of Radiotherapy
GMC, Patiala

The Ph.D Viva-Voice examination of **Shekhar Dwivedi (16406MPE01)** Research Scholar, has been held on _____.

Sign of Supervisor **Sign of Co-Supervisor** **Sign of External Examiner**

DEDICATION

MY DEGREE OF DOCTOR OF PHILOSOPHY IS DEDICATED TO MY PARENTS

ACKNOWLEDGEMENT

I still can't believe my PhD journey has come to an end. During my Ph.D. tenure, I worked with a large number of people who made significant contributions to the research and thesis writing in various ways. I gained important knowledge during this period and a very valuable academic experience. These were possible through the direct or indirect contributions of many people, whom I would like to thank.

I believe that first and foremost I owe a debt of gratitude to my parents for bringing me up to be the person that I am today, for having faith in me, and for allowing me the freedom and space to develop in whatever way I deemed appropriate. You have never wavered in your commitment to offering me assistance in any form. This work, this thesis, is dedicated to both of you, Mammi and Papa. Thank you!

I would like to express my most sincere gratitude to the most important people without whom this was absolutely not possible are my Ph.D. supervisor, Prof. Sandeep Kansal, Department of Physics, MRSPTU, Bathinda and co-supervisor, Dr. Vinod Kumar Dangwal, Associate Prof. (Medical Physics), Department of Radiotherapy, GMC, Patiala for their unwavering support during my Ph.D. study and research, as well as for their patience, motivation, enthusiasm, and vast knowledge. Their guidance helped me during my Ph.D. research work and writing of this thesis. I could not have dreamed of having a better advisor and mentor for my Ph.D. study.

During the time that I was working toward my Ph.D., I was fortunate enough to have the unwavering support of my Ph.D. mates, Dr. Amit Singla, and her wife, Ms. Supriya. I would like to take this opportunity to convey my deepest gratitude to both of them. It would never have been possible for me to take this work to completion without their incredible support and encouragement.

I thank to Prof. Buta Singh Sidhu, Vice-chancellor, MRSPTU, Bathinda for their encouragement and assistance during my research.

It is my privilege to express heartfelt thanks and sincere gratitude to Madam Mamta Kansal, Associate Professor and Head, Department of Mathematics, MRSPTU, Bathinda, for providing her valuable support and teachings during my Ph.D. course work. I am immensely grateful to her.

My sincere thanks also goes to Mr. Rahul Menon, Jr. Tech. (Grade-II), Department of Physics, MRSPTU, Bathinda, and Mr. Jaswinder Singh, Jr. Assist., University Business School, MRSPTU, Bathinda, India for their support during my thesis work.

In addition, I would like to take this opportunity to thank the non-teaching staff of the department for providing administrative and other types of assistance during this time period.

Finally, I would like to extend my warmest regards and gratitude to my parents for their dedication to my ambition, affectionate company, moral support, and selfless personal sacrifices, and to my brother and sisters for being a constant source of motivation that helped me throughout my work. I'm also grateful to all my family members, friends, and well-wishers for all the support they gave me during this period.

Shekhar Dwivedi

LIST OF FIGURES

LIST OF TABLES

PREFACE

In the present study, small field dosimetry, stereotactic body radiotherapy (SBRT) treatment planning, and dose verification procedures for a 6 MV FFF beam have been investigated. The thesis is divided into six chapters.

CHAPTER 1: INTRODUCTION

This chapter provides an overview of cancer, radiotherapy, linear accelerators, flattening filter (FF) and flattening filter-free (FFF) photon beams, small field dosimetry and detectors, radiotherapy planning, treatment planning system, and patient-specific quality assurance (QA). It includes a detailed literature review on FFF photon beams, treatment planning, and pretreatment QA, as well as the objectives of the current investigation.

CHAPTER 2: INSTRUMENTATION

This chapter focuses on the specific instruments and devices, such as linear accelerator, radiation field analyzer, various radiation detectors, phantoms, treatment planning system, and pretreatment verification devices that were utilised to achieve the defined research objectives.

CHAPTER 3: DOSIMETRY OF A 6 MV FFF SMALL BEAM USING VARIOUS DETECTORS

This chapter deals with the measurement of small fields using ionization chambers, thermoluminescent dosimeters (TLDs), diode detectors, and radiochromic films. The 6 MV flattening filter-free (FFF) photon beam was used for measurement of output factor, depth dose, and beam profile of small-fields of sizes 0.6 cm × 0.6 cm to 6.0 cm × 6.0 cm. All measurements were performed as per the International Atomic Energy Agency TRS 483 protocol.

CHAPTER 4: DOSIMETRIC COMPARISON OF DIFFERENT PLANNING TECHNIQUES BASED ON FFF BEAM FOR LUNG SBRT

In this chapter, the dosimetric comparison and evaluation of flattening filter-free (FFF) photon beam-based three-dimensional conformal radiotherapy (3DCRT), intensity-modulated radiation therapy (IMRT), and volumetric modulated arc therapy (VMAT) for lung stereotactic body radiotherapy (SBRT) have been discussed.

CHAPTER 5: DOSIMETRIC COMPARISON OF THE MONO- AND DUAL-ISOCENTRIC VMAT TECHNIQUE FOR SPINAL SBRT

This chapter evaluates the planning characteristics of spinal stereotactic body radiotherapy (SBRT) using mono- and dual-isocentric volumetrically modulated arc therapy (VMAT) techniques. The dosimetric indices were compared between different beam arrangement techniques for spinal SBRT planning, including spinal cord avoidance, planning target volume (PTV) dose coverage, conformity, homogeneity, and gradient index.

CHAPTER 6: DOSIMETRIC EVALUATION OF FOUR PRETREATMENT VERIFICATION DEVICES FOR LUNG AND SPINAL SBRT

This chapter compares the four different pretreatment verification tools (MapCHECK 3, ArcCHECK, Portal Dosimetry, and PerFRACTION) for stereotactic body radiotherapy (SBRT) plans. These SBRT plans were generated on an anthropomorphic RANDO man phantom using volumetric modulated arc therapy (VMAT) techniques and a 6-MV flattening filter free (FFF) photon beam.

Finally, the conclusion and scope of future work have been discussed.