Creation of

Dosimetric Verification for Implementation of Intensity Modulated Radiation Therapy (IMRT) Validates Using Polymer Gel

Thesis Submitted by

Medhat Shaban El-Sayed Mansour

M.Sc in physics (2007)

To Physics Department, Faculty of Women for Arts, Science and Education, Ain Shams university, Egypt for the award of the Degree of Ph.D. in Solid State Physics

Supervisors

Dr .Prof. Amira Zaky Dakrory

Professor of Experimental Solid State Physics, Physics Department, Woman Faculty for Art, Science and Education, Ain Shams University

Dr .Prof. Fathy Ebrahim Said

Professor of Radiation Chemistry, Atomic Energy Authority

Dr .Prof. Tarek Mohammed Hegazy

Professor of Radiation Physics, Woman Faculty for Art, Science and Education, Ain Shams University

Assiss Dr .Prof Heiam Abd El-Ghany

Assistance Professor of Radiation Physics, Woman Faculty for Art, Science And Education, Ain Shams University

2015

Creation of Dosimetric Verification for Implementation of Intensity Modulated Radiation Therapy (IMRT) Validates Using Polymer Gel

By

Medhat Shaban El-Sayed Mansour

M.Sc.

A DISSERTATION

IN

PHYSICS

Submitted to the Faculty Of women

Ain Shams University in Partial Fulfillment

0f the Requirements for The Degree of

PhD in Solid State Physics

Approved

National center for radiation research and technology

Atomic energy authority

2015

Acknowledgment

Above all, thanks to Allah who gives me support to complete this work I would also like to thank my supervisors; Prof. Dr. Amira Zaky El-Dakrory; Professor of solid state physics, physics department, women faculty, Arts, Science and education, Ain Shams University, Prof.Dr. Fathy Ebrahim Said professor and consultant of Atomic Energy Authority, radiation protection and dosimetry, Dr .Prof. Tarek Mohamed El-Dousky Hegazy, Professor of radiation physics, Physics Department, women faculty, for Art, Science and Education, Ain Shams University, and Dr. Hayam Ahmed Abd El-Ghany,. I am especially grateful to my wife hind and daughter fatma.

Abstract

Polymer gel dosimeter is a technique that has the ability to map absorbed radiation dose distributions in three dimensions (3D) with high spatial resolution, it offers a number of advantages over traditional dosimeters such as ionization chambers, thermo luminescent dosimeters (TLD) and radiographic film. These gels are reproducible in response and stable 0n post-irradiation. It is used as the monomer N-iso propyl acryl amide (NIPAM) and N, N–methylene bis acryl amide (Bis) as the cross linker. A historical overview of gel dosimeter was discussed in detail, inside the theses this case; nearly all data met the expected measurement error of 5 % of the maximum dose (50cGy). Relative errors were determined to decrease from 25 % at a 2Gy irradiation to 9.2% for a 10Gy irradiation The NIPAM polymer gel dosimeter system proved to be an invaluable method for the quantification of the 3-D dose distribution provided by IMRT. A measurement error of less than 5% was achieved. Toxicity and uncertain response to particular environmental characteristics (*i.e*., temperature and aging) upon the gel are of important concern about the use of the gel at this time. A PAG gel dosimeter is a method verifying dose delivered for prostate cancer

radiotherapy treatment, which has been evaluated in this work.

A comparison of DVH for PTV between the two treatment plans was verified experimentally. MRI response, the possibility was demonstrated of manufacturing gel dosimeters suitable for 3D dosimeter in the dose range. The results show that IMRT technique not only provides a better conformal dose to the prostate target volume than conventional Seven-field technique, but also reduces doses to the surrounding normal tissues, The aim of this study was to investigate the basic characteristics of the modified gel dosimeter such as temperature effects, magnetic field strength, PH, aging, energy and dose rate dependence This includes studies of relaxation time dose response, and stability of the measured dose distribution with time. The irradiated gel by linear accelerator after that evaluated by MRI so can also be used to obtain images of the 3-D dose distribution and evaluate dependence of polymer gel dosimeter $1/T_2$ on different mean dose rates. Using MRI, the formulation to give the maximum change in the transverse relaxation rate R_2 ($1/T_2$) was determined when the preparation of final polymer gel solution is completed, the R_2-dose response of the polymer gel dosimeter is linear between 4 to 10Gy. Dose rate dependence was studied in

6MV photon beam with the use of dose rates 80, 160, 240, 320, and 400cGy/min. Although the treatment time will be extended as more monitor units (MUs) are required to construct the same isocenter dose in the treatment. There are no substantial differences between 6MV (low) and 10MV (high) beam energy in treatment planning systems can produce a uniform and considerably equivalent dose plan. We attempt to reduce for toxicity as possible as N iso propanol acryl amide under limit for high risk factor measured by biological oxidant dioxin (BOD) to factor $2x10^6$ ng/dl we can not yet.

(%dd) percentage depth dose for (IMRT) intensity modulated radiation therapy / polymer gel & Magnetic resonance imaging = 6.7 %

%dd percentage depth dose for (IMRT) intensity modulated radiation therapy /ionization chamber and radiographic film(IC&RF) = 4.6%.

DVH dose volume histogram for polymer gel & magnetic resonance imaging = 94%.

DVH dose volume histogram for point by point ionization chamber and radiographic film = 86%.

Keywords

Polymer gel dosimeter, normal atmospheric condition (normoxic), radiotherapy, NIPAM, MRI, anti-oxidant, R_2-dose response, sensitivity, stability. Treatment volume (TV), treatment planning system (TPS)

Table of Contents

Acknowledgment..... i

Abstract..... ii

Table of Contents…….. vi

List of Tables..... xii

List of Figures..... xiii

Chapter 1: Introduction

1.1 Description of research problem investigated. 1

1.2 Overall objective of the study 1

1.3 Specific aims of the study 2

List of Abbreviations…….....5

Chapter 2: Background and literature review

2.1 radiotherapy 10

2.2 radiation dosimeter.....13

2.3 Current dosimeter techniques.....15

2.3.1 Calorimeter.....15

2.3.2 Chemical dosimeter.....16

2.3.3 Ionization chambers.....18

2.3.4 Film dosimeter.....19

2.4 Gel dosimeter.....21

2.4.1 Fricke gels.....21

2.4.2 Polymer gels.....22

2.4.2.1 BANG gels 23

2.4.2.2 PAG gels 25

2.4.2.3 Normoxic polymer gels.....26

2.4.2.4 Normoxic PAG gels.....30

2.4.2.5 Presage polymer dosimeter.....30

2.5 Advantages of gel dosimeter.....31

2.6 Gel dosimeter methodology.....33

2.7 Reaction process of polymer gels..... 35

2.8 Imaging of Polymer Gels.....37

2.3.1 Magnetic Resonance Imaging.....37

2.3.2 Optical Imaging.....38

3.3 X-ray Computed Tomography.....40

2.3.4 Fourier-Transform Raman Spectroscopy.....42

2.3.5 Ultrasound Imaging.....44

2.9 Radiotherapy Applications for Polymer Gels.....45

2.4.1 Intensity-Modulated Radiation Therapy (IMRT) 45

2.4.2 Stereo tactic Radio surgery and Radiotherapy.....46

2.4.3 Carbon Ion Therapy.....47

2.4.4 Brach therapy.....48

2.4.5 Boron Neutron Capture Therapy.....50

2.5 Prostate Cancer Treatment

2.5.1 Anatomy of Prostate.....51

2.5.2 Prostate Cancer.....53

2.5.3 Treatment options for prostate cancer.....54

Dosimetry Validation

2.6 Gel Response Studies

2.6.1 Introduction.....55

2.6.2 Temperature Effects.....56

2.6.3 Weight Fraction Variation.....56

2.6.4 Energy and Dose Rate Dependence.....57

2.6.5 Other Response Effects: Magnetic Field Strength, pH Studies and Gel Aging……..59

Chapter 3: Material and Methods

3. Gel dosimeter methodology…….....……60

3.1 Reaction process of polymer gel…….....…..…61

3.1.2 Equipment Overview……..…..62

3.2 Gel preparation……..……63

3.3 Gel Irradiation……..……70

3.4 MRI Evaluation……..…….76

3.4.1 Magnetic Resonance Imaging (MRI)……..…..76

3.4.2 Imaging of the Polymer Gel……...…..76

3.5 MRI Scanning……...…..80

3.6 Data Analysis……..82

3.7 MRI analysis……...……82

3.8 Gel Calibration……...…….89

3.9 Treatment planning system and verification

3.9.1 Film and ionization chamber calibration……..92

3.10 Prostate Case Dosimeter……....……94

3.10.1 IMRT Methods……..……94

3.10.2 Dose Verification……...…….95

Chapter 4: Result

4. R_2-Dose Calibration Curve ……..……..96

4.1 Calibration Curves to Gel Dosimeter…….....97

4.2 Dose Maps

4.2.1 The dose response relation…….101

4.3 Dose Distribution…….103

4.3.1 Patient IMRT plan for a prostate cancer treatment103

4.3.2 Depth dose method……...……..106

4.3.3 Dose profile……107

4.3.4 Dose Volume Histogram (DVH)……..….110

4.4 Prostate Case Dosimeter for IMRT……..112

4.4 1 Validating IMRT (Ionization chamber and radiographic film)…….…..122

4.5 Dose profile ……..……125

4.5.1 Dose Volume Histogram (DVH) …….....…..126