Determination of Dose Distribution of Ruthenium-106 Ophthalmic Applicators

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Thesis submitted for the degree of
Master of Science (Medical Physics)
In the University of Adelaide
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August 2003

Contents

Abstract

Dose distributions of COB and CCA type ruthenium-106 ophthalmic applicators, of diameters 15 mm and 20 mm, respectively, were investigated using small $CaSO_4$:Dy thermoluminescent dosimeters. The $CaSO_4$:Dy TLD discs were irradiated with a 4MV linear accelerator (Varian Clinac 4/100) at the Royal Adelaide Hospital. A range of absorbed doses from 0.1 to 10 Gy was used to observe their reproducibility and linearity. This machine was selected because it provides an electron beam with an energy of approximately 1.3 MV that is close to the mean energy of beta particles produced by the decay of ruthenium-106. A TOLEDO Model 645D TLD Reader was used to readout the irradiated TLDs. It was found that these TLDs respond linearly to radiation doses up to 6 Gy above which supralinearity begins. A sensitivity factor for each TLD disc was measured and applied to subsequent readouts. Selected TLD discs were cut into small rectangular wafers with dimension of approximately 2 x 3 x 0.4 mm^3. The same method as described above was employed to obtain the sensitivity factor for each small TLD. Their relative dose response sensitivities ranged around the mean from approximately -20% to +17%.

Dose distributions of ruthenium plaques were observed by placing the small TLDs in different positions on an eye phantom. Eye phantoms were made of layers with different thicknesses and can be built up from 1 mm to 10 mm. The results showed that the radioactive layer was non-uniform on each plaque. Hot spots and cold spots were found in various positions throughout the plaques. In comparison to the depth dose values provided by the plaque manufacturer, the depth dose values measured by these small TLDs were

lower, and the percentage uncertainties were considerably improved. The highest uncertainty obtained was approximately ±10% compared with ±30% specified by the manufacturer. Determination of on-axis depth dose distributions of ruthenium-106 applicators was also conducted with the MOSFET semiconductor dosimeter. Its high sensitivity to radiation doses, instant readout and a simple measurement setup are some advantages of the MOSFET dosimeter. On-axis depth dose distributions measured with the MOSFET dosimeter were comparable with those measured with the small TLDs and those provided by the manufacturer ($\sigma = 8\%$).

Declaration

This work 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 available for loan and photocopying.

SIGNED:_____ _____ **DATE:** 1-8-2003

Acknowledgments

I wish to thank Australian Agency for International Development (AusAID), Australian Government, who gives me a great opportunity to come and study at University of Adelaide under the Australian Development Scholarship (ADS). Without their support and generosity, I would not be able to come this far to fulfill the dream of a mother to see her son getting as much education as possible.

I would like to also thank to my superiors, Mr. Poonsuk Pongpat, Director of Radiological Measurement Division (formerly Director of Health Physics Division), Mrs. Pentip Khunarak, Head of Radiological Hazard Analysis and Assessment Section, at the Office of Atomic Energy for Peace, to theirs support and help me in receiving this Australian Development Scholarship.

I am very grateful for the supervision and guidance of Dr. John R. Patterson, my supervisor. He was very helpful and supportive during my study at the University of Adelaide. In the passing two years that I have been studying at the university, I confronted several difficulties of being an overseas student. With his invaluable supervision and guidance, I can survive those hard times and be able to continue my studying. Furthermore, I also thank for his organizational and financial support in helping me to attend the conference and present my research findings and, in addition, proof reading this thesis.

I would like to thank the Royal Adelaide Hospital Departments of Radiation Oncology and Medical Physics for use of facilities. A year of completing my research project and writing my thesis would be very difficult without the supervision and guidance of Dr. Eva Bezak. With her experience and expertise in medical physics research that keep me in the right track and able to reach the aims of the research project. During this one year in doing my research project, I have gained a lot of knowledge in medical physics and research skills from Dr. Eva. Thank to her enthusiasm and willingness to provide her support and guidance in performing the experiments, writing this thesis and helping me to attend the conference and present my research report.

Thanks also to Mr. Kurt Byas for his expertise in TLD measurements. His supervision, guidance and support in performing experimental TLD measurements were invaluable. I am very appreciating for his enthusiasm and willingness to share his knowledge and friendship. The other staffs of the Medical Physics Department at the Royal Adelaide Hospital have all been very friendly and helpful, particularly Mr. Shane Hein who helped us in making the acrylic eye phantoms that were important instrument of this research experiments.

I wish to thank my colleagues at the Office of Atomic Energy for Peace, Siriluck Lumjiactas and Pennapa Kruakheo, who provide me the financial management. I would like to express my appreciate to my girlfriend, On-Anong Srasom, for giving me an inspiration, companionship and constant support from the beginning of the study until the last minute of finishing this thesis.

Finally, I would like to thank to my mother who always encourage her sons to obtain as much education as they can and become good and invaluable persons to community. I do really appreciate that and this thesis is dedicated to her.

Preface

Background

Ruthenium-106 ophthalmic applicators have been widely used for treatment of eye tumours and its clinical use has been developed for more than a decade (Taccini *et al.* 1997). It has been indicated in several reports that the treatment of those eye disorders with the ruthenium plaques (in selected cases), is an effective and reasonable method (Lim & Petrovich, 2000, and Gunduz *et al.*, 2000). Similar to other types of brachytherapy, the most important requirement for the use of ruthenium eye applicators is that the prescribed dose must be delivered to the target tissue with accuracy so an effective treatment is provided and the irradiation of healthy tissue is kept as low as possible. This important objective cannot be achieved without an understanding of the radiological characteristics of the ruthenium applicators such as dose distribution patterns in the eye ball and uniformity of the active layer (ruthenium-106) coated on the plaques. Hence, the determination of the dose distributions and uniformity of the active layer of the eye applicators should be carefully investigated. Although the radiological characteristics of the ruthenium applicators, such as absorbed dose rate and depth dose rate distribution, were provided with the purchase of the applicators, they have an uncertainty of ± 30% that is not acceptable for clinical use. Thus, an observation of the radiological characteristics of the applicators with an appropriate method providing an acceptable level of uncertainty is necessary.

Aims of the current research

Although improvements in the determination of the dose distributions of the ruthenium-106 ophthalmic applicators were achieved in previously published studies, evaluation of dose distribution characteristics of the ruthenium applicators needs be further investigated with the aim to obtain more accurate dose distribution patterns. Also, a simple and fast technique is needed to enable the routine measurement of radiation output of sources, for example to confirm the doses reported by the manufacturer (acceptance testing) or to check the integrity of the source after handling during treatments (quality assurance procedure). Some of the parameters to be investigated regularly may include the depth dose distribution (relative or absolute) along the central axis of the applicators, the horizontal dose distribution, and the homogeneity of the radioactive material distribution (ruthenium-106) in the applicators. Correspondingly, the specific aims of the presented research project include:

1. Determination of dose distribution characteristics of COB-494 and CCA-610 type ruthenium-106 applicators used for eye radiation treatments at the Royal Adelaide Hospital. Dose distribution patterns of these particular applicators in great details have not been reported previously.

2. Determination of dose distribution values (central depth dose and off-axis dose) for both mentioned ruthenium-106 applicators with an uncertainty acceptable (below 10%) for clinical use.

3. Development of a standard dosimetry method that can be used for evaluation of the dose distributions of ruthenium-106 applicators for routine quality assurance purposes.

In order to achieve this, two dosimetry methods were employed in the current work: small $CaSO_4$:Dy thermoluminescence dosimeters and a semiconductor MOSFET dosimeter (the use of which has not been so far reported in literature). Correspondingly, the structure of this thesis is as follows: The general properties of ruthenium-106 applicators and previous studies about theirs dosimetry were provided in chapter 1, the general principles of thermoluminescent dosimetry will be summarised in chapter 2, followed by the study of properties of $CaSO_4$:Dy TLD (sensitivity, dose linearity, reproducibility, etc) in chapter 3. Chapter 4 will deal with the experimental details and results of the application of small $CaSO_4$:Dy TLDs to dose investigation of Ru-106 ophthalmic applicators and chapter 5 will discuss the application of MOSFET dosimeter for determination of applicator relative depth dose curve. Finally, the results of the current work will be summarised in chapter 6.

The publications and presentations with which the author has been participated during the course of this research are:

Conference Presentations

Takam, R., Bezak, E. & Byas, K. (2002). Determination of Dose Distributions of Ruthenium-106 Ophthalmic Applicators. **15th National Congress of the Australian Institute of Physics, AIP, July 8 – 11, 2002, Sydney.**