THE COMPARISON OF DOSIMETRIC PROPERTIES BETWEEN GAFCHROMIC EBT-2 FILM AND RTQA FILM IN HIGH ENERGY PHOTON BEAM AND HIGH ENERGY ELECTRON BEAM

BY

NOR FATHIN HALINA BINTI NAZLIE LEONG

Dissertation submitted in partial fulfillment of the requirement for the degree of Bachelor of Health Sciences (Medical Radiation)

June 2016

CERTIFICATE

This is to certify that the dissertation entitled "The Comparison of Dosimetric Properties Between Gafcromic EBT-2 Film and Gafchromic RTQA Film in High Energy Photon Beam and High Energy Electron Beam" is the bona fide record of research work done by

NOR FATHIN HALINA BINTI NAZLIE LEONG (116606)

During the period from January 2016 to May 2016

Under the supervision of,

Supervisor,	Co-Supervisor,
____________________	____________________
Mr. Mohd Fahmi B. Mohd Yusof, Lecturer, School of Health Sciences, Universiti Sains Malaysia, Health Campus, 16150 Kubang Kerian, Kelantan, Malaysia.	Mr. Reduan B. Abdullah, Sciences Officer, School of Health Science, Universiti Sains Malaysia, Health Campus, 16150 Kubang Kerian, Kelantan, Malaysia.
Date :	Date :

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful.

Alhamdulillah, Praise to Allah for His countless blessings and the strengths to complete this thesis. My special appreciation goes to my supervisor, Mr. Mohd Fahmi B. Mohd Yusof for his guidance, constant support and encouragement throughout this research. My sincerely thanks to my co-supervisor, Mr. Reduan Abdullah for spending his precious time to guide me.

Deepest thanks and appreciation to my family especially my beloved mom, Che Esah Binti Yusoff for full of support, pray for me and give me motivation to finish this research. To all my lecturers that has given me knowledge throughout the period of my studies, that manage me to gain new experience and knowledge in this field. And to my entire classmate especially all the students that was done their final year project with same supervisor with me, thank you for sharing knowledge with me and helped me when I needed.

Last but not least, for all the peoples that has contributed directly or indirectly helps me in this research project. I want to thank you for all the help and information that have been shared and given.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

LIST OF ABBREVIATIONS

IC	Ionization Chamber
LINAC	Linear Accelerator
OD	Optical Density
PDD	Percentage Depth Dose
SSD	Source- to- surface Distance
TPS	Treatment Planning System
cGy	centiGray

ABSTRACT

The aim of this work was to compare the dosimetric properties between Gafcromic EBT-2 Film and Gafchromic RTQA Film in high energy photon beam and high energy electron beam. For calibration purpose, both films were cut into 3 cm x 3 cm and irradiated from 0 cGy to 600 cGy in 6 MeV, 9 MeV electron beam and 6 MV, 10 MV photon beam. For measuring percentage depth dose and beam profile, another RTQA film and EBT-2 film was irradiated with 400 MU. Then, all the film was scan by using Gafchromic Film Scanner (Flatbed Scanner EPSON EXPRESSION 10000 XL) after 24 hr irradiated. The result was analyzed by using Verisoft Software 5.1. The result shown EBT-2 film is more sensitive up to 6 Gy compare to RTQA film. The result of percentage depth dose for both films were compare to the result of ionization chamber and treatment planning system. The EBT-2 film shown in a good agreement with ionization chamber and treatment planning system compare to RTQA film. All the results of beam profile for RTQA film seen in a good agreement with EBT-2 film in terms of beam flatness and penumbra size. As a conclusion, the EBT-2 film is more suitable to be used in measured PDD and beam profile in high energy electron and photon beam.

ABSTRAK

Tujuan kajian ini adalah untuk membandingkan sifat-sifat dosimetri antara Filem Gafcromic EBT-2 dan Filem Gafchromic RTQA dalam sinaran tenaga foton yang tinggi dan sinaran tenaga electron yang tinggi. Untuk tujuan penentukuran, kedua-dua filem telah dipotong menjadi 3 cm x 3 cm dan radiasi dari 0 cGy hingga 600 cGy dalam 6 MeV, 9 MeV alur elektron dan 6 MV, 10 MV sinaran foton. Untuk mengukur peratusan kedalaman dos dan pancaran profil, filem RTQA lain dan EBT-2 telah diradiasi dengan 400 MU. Kemudian, semua filem itu telah diimbas dengan menggunakan Gafchromic Filem Scanner (Flatbed Scanner EPSON EXPRESSION 10000 XL) selepas 24 jam sinaran. Hasilnya telah dianalisis dengan menggunakan Verisoft Software 5.1. Hasil ditunjukkan filem EBT-2 adalah lebih sensitif sehingga 6 Gy jika dibandingkan dengan filem RTQA. Hasil kedalaman peratusan dos untuk kedua-dua filem itu dibandingkan dengan hasil kebuk pengionan dan sistem perancangan rawatan. Filem EBT-2 menunjukkan dalam perjanjian yang baik dengan kebuk pengionan dan sistem perancangan rawatan berbanding dengan Filem RTQA. Semua keputusan sinaran profil untuk filem RTQA dilihat dalam perjanjian yang baik dengan EBT-2 filem dari segi kerataan sinaran dan saiz penumbra. Secara kesimpulannya, filem EBT-2 lebih sesuai digunakan untuk mengukur kedalaman peratusan dos dan alur profil dalam pancaran foton dan elektron yang tinggi.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Radiotherapy remains the most important non- surgical treatment in the management of cancer. Over 50 % of patients will receive treatment at some time during the management of their malignant tissue (Peter Hoskin, 2012). Radiotherapy is a technique of the cancer treatment to kill or control the malignant cell growth using ionizing radiation. The treatment can be done either from the outside (external beam therapy) or inside the body (brachytherapy) (Hazila, 2014).

In order to access the dose distribution, a reliable dosimeter is required. Dosimeter plays an important role in the measures the radiation dose. A number of researchers have reported using ionization chambers, semiconductors, thermoluminescent detectors (TLDs) and films as a dosimeter. Recently, researchers have shown an increased interest in using radiohchromic films as a dosimeter for radiotherapy dosimetry (Hazila, 2014).

The measurement of dose distribution in the entire plane along the beam axis can be used both silicon detectors and radiochromic films. However, dose distributions were more precise with the radiochromic films because these sheets are able to capture the dose over the entire area of the film whereas silicon detectors can only measure the dose at a specific location, resulting in less precise spatial resolution (Borowich et al., 2014).

Tsao et al (2004) stated that Gafchromic film provides superior spatial resolution, easy to handle because of its insensitivity to room light. Initially, Gafchromic film was transparent and change to a darker color when it was exposed to the ionizing radiation. Radiochromic films are self-developed film as it do not require the chemical processing.

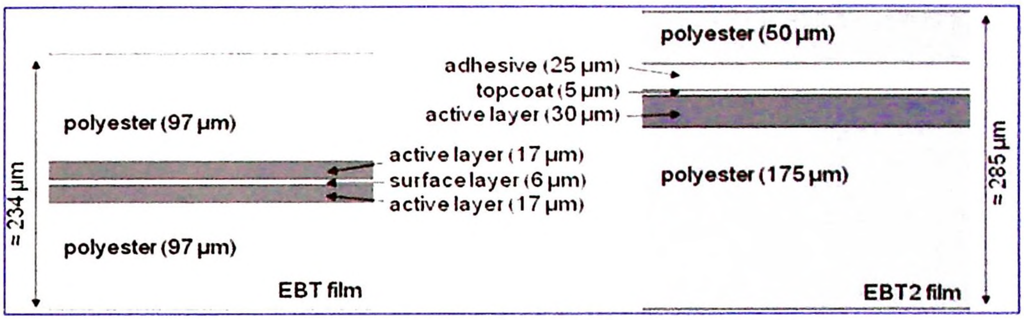

Figure 1.1 : Structure of EBT-2 film compared with EBT film as stated by the manufacturer

EBT film, the predecessor of EBT-2 film, has been shown to produce best results when stored at or below room temperature in light-tight packaging, touched only at the edges and scanned at least 24 hour after irradiation (Martisikova et al, 2008). Additionally, to reduce or correct for the sensitivity of measured dose to properties of the film scanner, it has been recommended that EBT films be scanned in the centre of the scanner, with a consistent orientation, and with a minimal number of consecutive scans (Devic et al., 2005). Based on the results from another study, it is possible to recommend the use of EBT-2 film in routine quality assurance testing for radiotherapy, in situations where a dose uncertainty of up to 2.8% is acceptable (Alan et al., 2011).

The Gafchromic EBT-2 radiochromic film is widely used as indirect dosimeter for high energy photon and electron. The second generation EBT-2 provided slightly lower sensitivity in terms of its change in optical density per unit dose and that had proven to be a viable alternative to its predecessor (EBT) in clinical practice (Aldelaijan et al., 2011).

RTQA Gafchromic film is an alternative film which can be utilised for radiotherapy quality assurance procedures and provides some advantages over commonly used radiographic films. These advantages include its lower energy dependence which means it can be more easily used over the extended energy range from kilovoltage to megavoltage x-ray beams with an order of magnitude less difference in the applied dose required for a similar optical density change. As it is automatically developing, it can be analysed in position on the accelerator or superficial machine which provides a significant time efficiency gain and increases easy of calibration procedure and finally it can be used for multiple exposures in series to provide improved time efficiency compared to radiographic film (Butson et al., 2008).

The treatment planning and dosimetry are the main steps in radiotherapy, which includes calibration of the equipment, determination of absorbed dose under reference conditions, phantom measurements under non-reference conditions, calculation of dose distribution in the patient and, finally, treatment delivery via monitor units or treatment time calculation. Consideration of the uncertainties and their propagation increases the demand for accuracy in the dose calculation algorithm employed in the treatment planning. Therefore, quality assurance (QA) is necessary in the commissioning stage of the treatment planning system (TPS) prior to their use in clinical practice (Oinam et al., 2011).

1.2 AIM

To study the dosimetric properties of GafChromic EBT-2 film and GafChromic RTQA film in high energy photon and electron beam.

1.3 OBJECTIVES

- To compare the calibration curve with different energy between EBT-2 film and RTQA film.
- To compare the PDD curve of 6 MV and 10 MV photon beam and 6 MeV and 9MeV electron beam between EBT-2 film and RTQA film.
- To compare the beam profile of 6 MV and 10 MV photon beam and 6 MeV and 9 MeV electron beam between EBT-2 film and RTQA film.
- To measure the discrepancy of EBT-2 film and RTQA film to that of IC and TPS in photon and electron beam.

1.4 SIGNIFICANCE OF THE STUDY

The main purpose of this study is to know the comparison of the dosimetry properties between Gafchromic EBT-2 film and Gafchromic RTQA film in External Beam Therapy and to know the discrepancy of both film in comparison of ionization chamber (IC) and treatment planning system (TPS). Through this research, we could compare the calibration curve, PDD curve, beam profile and dose distribution between Gafchromic EBT-2 film and Gafchromic

RTQA film. The energy that used are 6 MV and 10 MV photon beam and 6 MeV and 9 MeV electron beam.

1.5 SCOPE OF THE STUDY

The study was conducted at Nuclear Medicine and Radiotherapy Department Hospital University Sains Malaysia, Kubang Kerian, Kelantan. The Gafchromic EBT-2 film and Gafchromic RTQA film was used to measure the dose uniformity for External Beam Therapy and in treatment planning system. In external beam therapy, Gafchromic EBT-2 film and Gafchromic RTQA film were used to compare the PDD curve by using dose at Dmax and beam profile was analyzed in term of penumbra and flatness.

CHAPTER 2

LITERATURE REVIEW

A study conducted by Alan et al., (2011) examines the dosimetric accuracy of Gafchromic EBT-2 model radiochromic film for quality assurance in radiotherapy. Two methods were used when analyzing the raw film scan data. The first was the standard method of analysis developed for EBT film, where only the red channel data is used. The second was the method recommended by the manufacturer specifically for EBT-2 film (ISP., 2010), where both the red and blue channel data are considered. Herein, these methods are referred to as the 'red' and 'red:blue' methods respectively. Results of this study suggest that the conversion of film optical density to measured dose should, at present, utilize red channel data only, without application of a blue channel correction to the data because the 'red:blue' method results in increased uncertainties in the resulting optical densities.

Besides that, Alan et al., (2011) studied the orientation of the film on the scanner and the side of the film facing the light source. Since EBT-2 film contains an active layer with the same composition as the active layer in EBT film, it can be expected to be similarly subject to the effects of scanning orientation. The result of scanning the films at a range of orientations, relative to the orientation at which the calibration films were scanned. Errors resulting from scanning the measurement film at a different orientation from the calibration film ranged up to 31.6 % of the dose (for the film irradiated to 100 cGy and scanned at 90^{o}). A scanning alignment error of 1^{o}, was found to lead to a maximum dose error of 0.7 %.

Additionally, due to asymmetric layer configuration in the construction of EBT-2, it is necessary to test whether this feature affects the optical density of the film. The effect of scanning with different sides of the film facing towards the scanner light source was investigated for six film pieces irradiated to 200 cGy. The average difference between the dose measured with one side of the film facing the scanner and the dose measured with the other side of the film facing the scanner was found to be within 2.4 %.

Alan et al., (2011) also conducted a study about the response of film. In order to create a film response curve, 14 film pieces from the same sheet of film were irradiated to 20 different doses from 0 to 400 cGy. The results clearly indicate an initial increase in dose within the first 5 hour after irradiation, followed by a levelling out of the dose after that period. During the initial period, the increase in dose was found to range from 8 % for 300 cGy to 12 % for 100 cGy. After the initial 5 hr period however, the dose still shows a trend to increase with time. If films are scanned within a 2 hour window relative to one another, then the dose uncertainty will be within ±0.5 %. Moreover, if the calibration films are scanned 24 hr after irradiation and the clinical films are scanned only 2 hour after irradiation, then there will be a 4.0 % uncertainty in dose.

According to Butson et al., (2008) that conducted a study about the measuring energy response for RTQA Radiochromic film to improve quality assurance procedures. Results show that the RTQA film produces an energy dependent darkening to x-rays which results in x-ray energies of 69 keV photon equivalent (150 kVp) to produce 2.14 times the optical density to dose ratio of a 6 MV x-ray beam. The following dose ratio's (normalized to 1 at 150 kVp) provide the same net optical density change for RTQA film. Although the film is not designed to be used as a quantitative measure of radiation it is still useful to know its energy response at differing x-ray energies to expose the film to the appropriate dose to provide optimal darkening characteristics for a given quality assurance test at the appropriate energy. The result shown that a 0.3 optical density change with RTQA film provides a color change level useable for accurate alignment procedures.

Borowich et al., (2014) conducted a study about accuracy of EBT and RTQA radiochromic film detectors in radiotherapy. Films were irradiated with the following doses: EBT films (0 to 3.0 Gy) and RTQA (0 to 3.5 Gy). These small pieces were used to determine the film response to the indicated dose and to calibrate the detectors and scanner at the same time. One piece of each type of radiochromic film was left unexposed in order to characterize a 0 Gy dose. The other pieces were irradiated perpendicularly to the central axis of the beam. Result shown response to radiation is higher on the EBT film than the RTQA film. For example, at an irradiation dose of dose of 1.5 Gy, the Net OD for EBT and RTQA, respectively, were 0.395 and 0.262.

A study conducted by Spunei et al., (2014) about the experimental results in percentage depth dose (PDD) determination at the extended distances. All measurements were taken using as radiotherapy unit the CLINAC 2100SC, produced by VARIAN. The energy used is 6 MV photon beam with a dose rate of 240 cGy/min. For absolute measurements, a setup composed from thimble ionization chamber PTW Farmer type 30001 and universal dosimeter UNIDOS from same company. The relative measurements were performed using water phantom MP3, two identical semiflex ionization chambers with sensitive volumes of 0.125 cm^3 and TANDEM dual channel electrometer all produced by the same PTW company. The relative difference between measured and calculated PDD at SSD = 100 cm is below 2 % for depths until 10 cm in phantom for smaller field (until 36 cm × 36 cm) but is increasing until 10 % in the maximum depth measured of 25 cm due to the phantom limitations.

Nikolovski & Lukarski., (n.d) conducted a study about the comparison between three differences linear accelerator. The data was presented from the dosimetric comparison of the two Varian Clinacs 23EX and one Varian Clinac iX. Both Percentage Depth Dose (PDD) and Beam Profile (BP) curves were compared for the photon energies (6MV, 15MV) and the comparison was performed using the IBA OmniPro Accept 7.4™ software. The results from the comparison of the PDD curves showed that in the clinically significant region the dose differences were smaller than 1%.The results from the comparison of the inline and crossline BP curves showed that in the flattened area the dose differences were smaller than 2.5 %, while in the penumbra region they were usually between 2 % and 8 %, but sometimes up to 21 %.

Oinam et al., (2011) conducted a study to evaluate the dosimetric performance of the Treatment Planning system (TPS) with three-dimensional dose calculation algorithm using the basic beam data measured for 6 MV X-rays. Eleven numbers of test cases were created and are used to evaluate the TPS in a homogeneous water phantom. These cases involve simple field arrangements as well as the presence of a low-density material in the beam to resemble an air in-homogeneity. Absolute dose measurements were performed for the each case with the MU calculation given by the TPS, and the measured dose is compared with the corresponding TPS calculated dose values. The result yields a percentage difference maximum of 2.38 % for all simple test cases. For complex test cases in the presence of in-homogeneity, beam modifiers or beam modifiers with asymmetric fields a maximum percentage difference of 5.94 % was observed. This study ensures that the dosimetric calculations performed by the TPS are within the accuracy of ±5% which is very much warranted in patient dose delivery. The test procedures are simple, not only during the installation of TPS, but also repeated at periodic intervals.

Sardari et al., (2010) was study about the measurement of depth-dose of linear accelerator and simulation. A water phantom with dimensions of 30 cm× 30 cm× 30 cm was simulated under the gantry with a source-surface distance (SSD) of 100 cm. There is good agreement between computed and measured PDD, especially for depths less than 200mm. This agreement fails around the dose build-up point. The uncertainty in computations amounts to 20% for locations deeper than 250mm and around the dose build-up point. Usually, for larger field size the agreement between measurement and computation in Z direction becomes better. With increasing depth, the uncertainty of computed dose distribution in the lateral direction decreases from 10 % to 5 %. As a whole, the computational results are satisfactory at depths between 50 and 200 mm.

Sardari et al., (2010) also stated that to obtain accurate results from Monte Carlo simulations in radiotherapy calculations, precise modelling of the LINAC gantry and a sufficiently large number of particles are required. In order to obtain similar standard deviations the number of primary events needed for fields of larger size is smaller than that for narrow fields: 4 × 109 primary electrons for a 5 × 5 cm^2 field, 3 × 10^9 electrons for a 10 × 10 cm^2 field, 2 × 10^9 primary electrons for a 20 × 20 cm^2 field and 10^9 primary electrons for a 30 × 30 cm^2 field. The most common variance reduction method is energy cut-off. Cut-off energy is the energy at which the Monte Carlo simulation stops transport of the particle if the particle's energy falls below the cut-off value. In all simulations, the energy cut-offs were 0.7 MeV for electrons and 0.01 MeV for photons.

CHAPTER 3

MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Gafchromic EBT-2 Radiochromic Film

Gafchromic EBT-2 Film was used in this study. A schematic of EBT-2 film cross section is given in figure 1 according to the manufacturer's specifications.

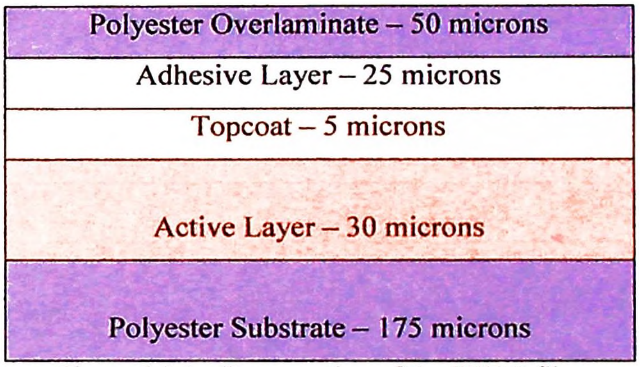

Figure 3.1.1 : Cross section of the EBT-2 film

Gafchromic EBT-2 film is constructed by a clear, polyester over laminate with the active film coating. The substrate of the active film is clear 700 gauge (175 micron) polyester. The substrate is coated with an active layer film, nominally 30 microns thickness, over which a topcoat, nominally 5 microns is applied. The over laminate, 200 gauge (50 microns) polyester with approximately 25 microns of pressure- sensitive adhesive, is bonded to the coated side of the active film. The over laminate protects the active layer/ topcoat from mechanical damage as well as from the effects of water and other liquids.

The EBT-2 film has wide range of dose dependent up to 40 cGy. The dose between 1 cGy to 10 gcGy is measured in red color channel wheres doses beyond 40 Gy is measured in green color channel. This feature has made the EBT-2 film suitable for the measurement of absorbed dose of high energy photon in (IMRT). The Gafchromic EBT-2 film design also has photon response that is nearly energy independent from about 50 keV into the megavoltage range. This has been accomplished by the careful adjustment of the atomic composition of the film. International Specialty Products (ISP) believes that response of EBT-2 film to 100 keV and 6 MV photons are within 10%.

The significant difference between Gafchromic EBT-2 film and its predecessor is the yellow color of the film. ISP has made a change to the Gafchromic EBT-2 film by adding a yellow dye incorporates in the active layer. The principal purpose of this dye is referred to as a marker dye that is to establish a reference against which the response of the film can be measured, resulting in a net response that is independent of small differences in the thickness of the active layer.

Gafchromic EBT-2 is self-developing, energy independent and can be use in the room light. It also can be cut easily to desired shape and size. It is preferable to use scissors or a guillotine cutter, but with care good results can also be obtained by using a scalpel or a sharp knife.

3.1.2 RTQA Film

Gafchromic RTQA Film also was used in this study. A schematic of RTQA film cross section is given in figure 1.2 according to the manufacturer's specifications.

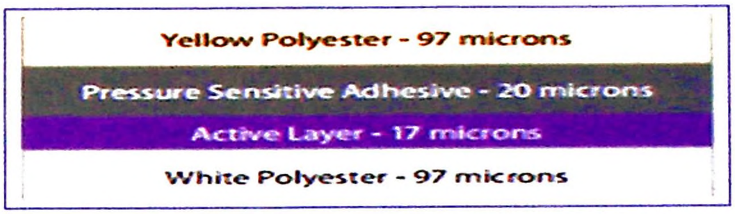

Figure 3.1.2 : Cross section of RTQA film

Gafchromic RTQA was designed for routine quality systems management of all modalities of radiotherapy with ease and confidence. It is a user friendly, cost effective, reliable and simple tool to meet quality assurance objectives. Gafchromic RTQA film used in qualitative dosimetry for faster, easier, more convenient and less costly quality assurance testing of radiotherapy sources and the commissioning of therapy equipment such as light- field and radiation- field alignment, star shots, positioning verification of high dose rate and autoradiography of implantable seeds, plaque and other sources.

Based on the manufacturer, RTQA film has one active layer and one layer of transparent polyester, colored in yellow and one layer of white non-transparent polyester (Borowich et al., 2014). It has the dynamic range from 0.02 Gy to 8 Gy, develops in real time that will eliminate the need of processor and chemical waste. Gafchromic RTQA film can be handled in room light, so the need of a darkroom can be eliminate. It also convenient to handle and easy to cut depends on size and shape that will need. Besides that, it is a water resistant and competitively priced compared to other film dosimeters.

3.1.3 Siemens PRIMUS Linear Accelerator (LINAC)

Figure 3.1.3 : Siemens PRIMUS Linear Accelerator (LINAC)

This linear accelerator was used to calibrate both films using the 6 MV and 10 MV photon beam also 6 MeV and 9 MeV electron beam. LINAC used to treat cancer by using high energy x- ray generator. LINAC has two beams which photon to treat deeper tumor and electron to treat tumor the superficial cancer. The energy produced from the 6 MV to 10 MV for the photon beam and 6 MeV to 21 MeV for electron beam. This machine has multileaf collimator (MLC) to shape the tumor.

3.1.4 Gafchromic Film Scanner (Flatbed Scanner EPSON EXPRESSION 10000 XL)

Figure 3.1.4 : Flatbed Scanner EPSON EXPRESSION 10000 XL

The scanning of film was performed using an Epson Expression 10000 XL flatbed scanner. The film was placed at the center of the scanner during scanning and it was scanned in the long axis direction. So, it can avoid the known homogenous scanner response towards the edges. The accurate result can be obtained if the film scans area and image resolution was consistent (Hazila, 2014).

The flatbed scanner Epson Expression 10000XL is a high-quality scanner with a reading area of 310 × 437 mm^2. It can read films in transmission or reflection mode up to a colour depth of 48 bits, a maximum resolution of 2400 dpi and a maximum optical density of 3.8. The incident light is a xenon gas fluorescent lamp captured by a linear charged coupled device (CCD) array (Capela, M. et al 2009). For EBT films, the absorption peak falls in the red region and therefore the red component of the image was extracted to maximize film readout (Fiandra et al 2006).

The verisoft software was used to analyze the calibrated film and film used for surface dose measurement. Lastly, this scanner can digitize images quickly and easily.

3.1.5 ONCENTRA Treatment Planning System

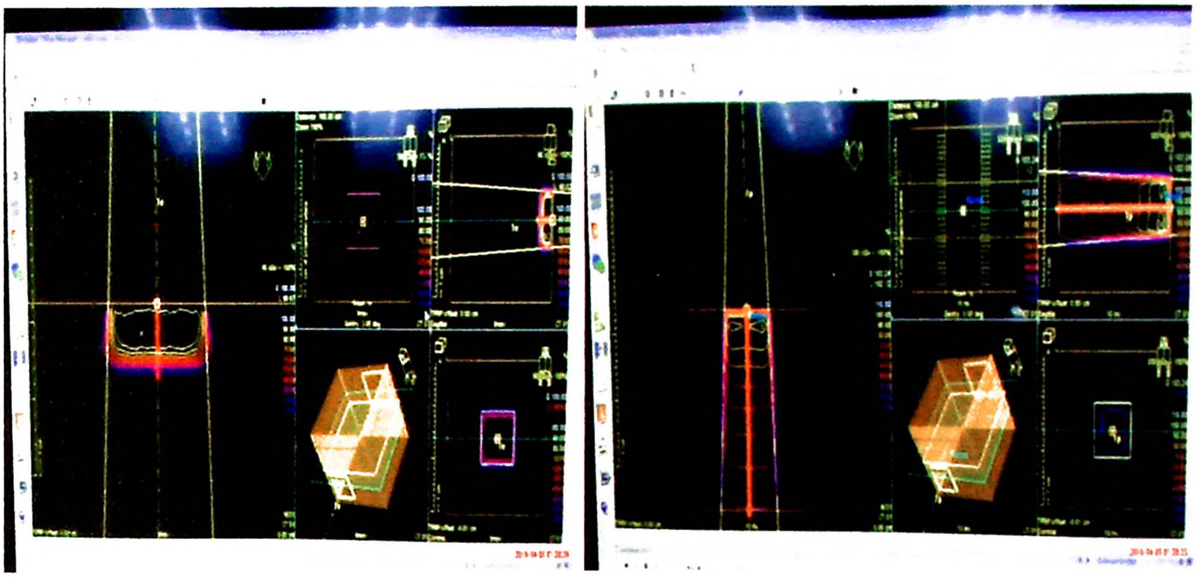

Figure 3.1.5 : ONCENTRA v4.3 Treatment Planning System

The treatment planning was a process to treat a tumor with radiation that can receive a uniform dose while can protect healthy tissue and critical organs. Oncentra v4.3 Treatment Planning System was used in this study. It was designed the optimal dose distribution can be a time-consuming job. Oncentra helps to optimize treatment plan accuracy, providing easy navigation to any plane that offers the most relevant information per region of interest. It also as a powerful inverse planning optimization automates volume-based planning, making the process fast and efficient.

3.1.6 Solid Water Phantom

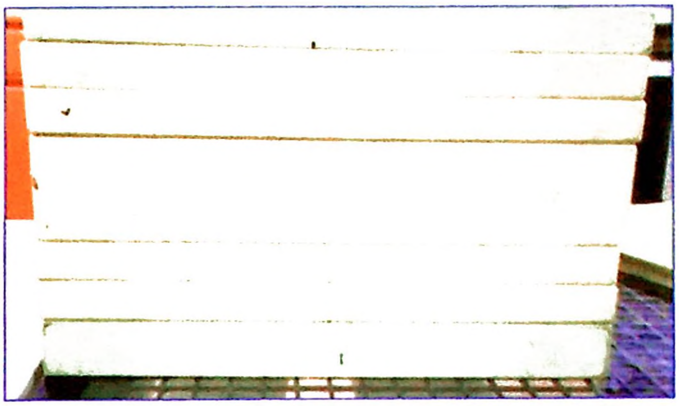

Figure 3.1.6 : Solid water phantom

Water is the standard phantom material for dosimetry measurements of photon and electron beams. Photon radiations in the range from 70 kV up to 50 MV and for electron radiation from 1 MeV up to 50 MeV are normally used in radiotherapy dosimetry. Solid water phantom is made from acrylic material or water- equivalent RW3 material (Goettingen White Water) with thickness tolerance of ±0.1 mm. The size of the solid water phantom was designed 30 cm x 30 cm with thickness range 0.50 cm to 5.00 cm.

3.1.7 Farmer-type ionization chamber

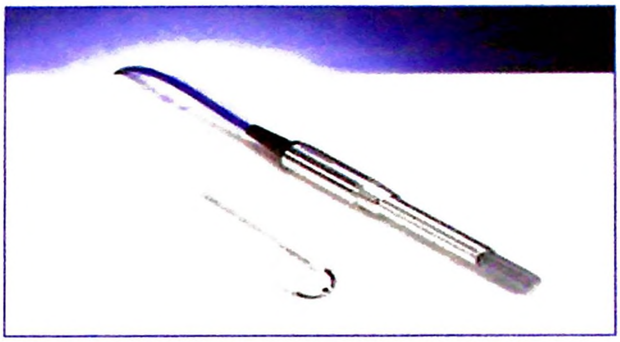

Figure 3.1.7 : Farmer- type ionization chamber

Farmer- type ionization chamber is a thimble chambers for measuring high-energy photon and electron radiation in air or in phantom material. It is vented sensitive volumes of 0.6 cm^3, suitable as therapy chambers for use in solid phantoms, flat energy response and a variety of different versions is available. The 0.6 cm^3 PTW Farmer chambers are designed for absolute photon and electron dosimetry with therapy dosimeters.

The electron energy range is from 10 MeV to 45 MeV. The guard rings of all chamber types are designed up to the measuring volume. An acrylic build-up cap for in-air measurement in ^{60}Co beams is included with each chamber, as well as a calibration certificate (PTW., n.d).

3.1.8 Markus Parallel- plate ionization chamber

Figure 3.1.8 : Markus parallel- plane ionization chamber

Markus parallel- plane ionization chamber is a plane parallel ion chamber for high-energy electron measurements in water and solid state phantoms. It is vented sensitive volume of 0.02 cm^3, wide guard ring design, suitable for relative and absolute electron dosimetry and the chamber is waterproof when used with protective cap.

A wide guard ring design to avoid perturbation effects by reducing the influence of scattered radiation from the housing. The small sensitive volume makes the chamber ideal for dose distribution measurements in a water phantom, giving a good spatial resolution. The chamber features a flat energy response within the nominal energy range from 2 MeV to 45 MeV. With the very thin membrane of only 0.03 mm polyethylene, the chamber is suitable for use in solid state phantoms. The chamber comes with a protective acrylic cover of 0.87 mm thickness (1 mm water equivalence) for use in water. A calibration certificate with a ^{60}Co calibration factor given in absorbed dose to water is included. Air density correction is required for each measurement. A radioactive check device is available as an option. The chamber cable length is 1.05 m (PTW., n.d).

3.1.9 UNIDOS® E Universal Dosimeter Electrometer

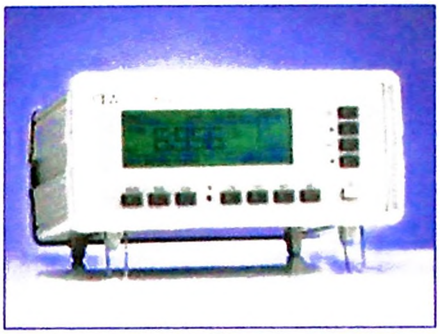

Figure 3.1.9 : UNIDOS® E Universal Dosimeter Electrometer

An electrometer is an electrical instrument for measuring electric charge or electrical potential difference. There are many different types, ranging from historical handmade mechanical instruments to high-precision electronic devices. UNIDOS® E features both mains and battery operation. It is easy to use reference class or field class dosimeter / electrometer for routine dosimetry.

The lightweight and compact UNIDOS®E is an easy to use dosimeter, mainly used for daily routine dosimetry in radiation therapy. Ion chambers and solid-state detectors can be connected. A chamber library makes it possible to store calibration data. Air density corrections are done by keying in air pressure and temperature. UNIDOS®E displays the measured values of dose and dose rate in Gy, R, Gy/min, R/min or Gy·m. The electrical values charge and current are measured in C and A. The device includes automatic leakage compensation. The high voltage between the ion chamber electrodes is checked automatically (PTW., n.d).

3.2.0 Barometer and Thermometer

Figure 3.2.0 : Barometer and Thermometer

Barometer and Thermometer used to precise air pressure and temperature measuring instruments for air density correction of ion chamber readings. The barometers provide precise measurement of absolute air pressure in hPa

The precision barometers and the thermometer are used to determine air density correction factors for absolute dosimetry. The temperature-compensated barometers have a circular analogue scale with 115 mm diameter. The scale resolution is 0.5 hPa. The metal housing is supplied with a flange for wall mounting.

The analogue precision thermometer is a mercury thermometer with a glass capillary. The measuring range is from 0 °C to 50 °C, and the scale resolution is 0.2 °C. The digital combined barometer and thermometer device is equipped with interfaces for data transfer to a PC (PTW., n.d).

3.2 METHODS

3.2.1 Film calibration with 6 MV, 10 MV and 6 MeV and 9 MeV beams

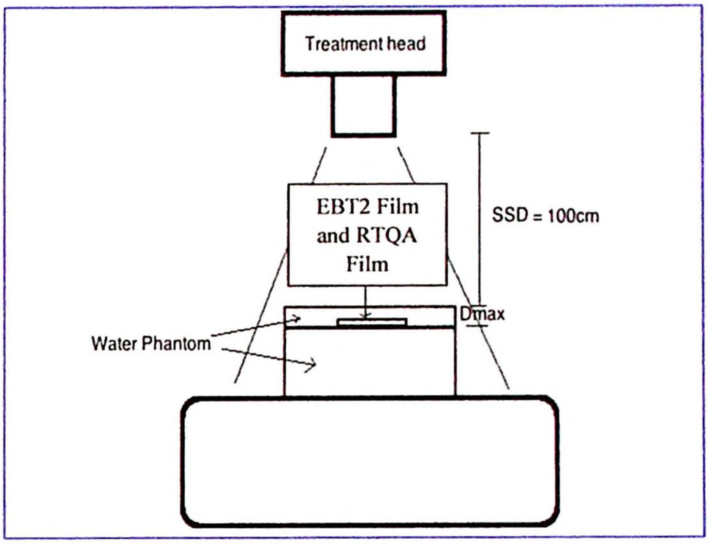

Figure 3.2.1 : The setup for calibration of EBT-2 film and RTQA film with 6 MV, 10 MV and 6 MeV Beam

GafChromic EBT-2 and GafChromic RTQA film were cut to a size of 30 mm x 30 mm. Eight dose points were employed for calibration starting from 0, 50, 100, 200, 300, 400, 500 and 600 cGy. All films were calibrated with the 6 MV, 10 MV, 6 MeV and 9 MeV beam from Siemens Linear Accelerator (LINAC). For 6 MV and 10 MV photon beam, the Source- to-Surface distance (SSD) is setup 100 cm, the depth of d_{max} is 1.5 cm is used to place the films in a solid water phantom with 30 cm x 30 cm x 11.5 cm with the field size is 10 cm x 10 cm. But for 6 MeV and 9 MeV electron beam, the SSD is same 100 cm but the value of d_{max} is 1.4 cm is used. After irradiated, all the calibration films were scanned using a flatbed scanner and data were analyzed after 24 hours.

3.2.2 Percentage Depth Dose and Beam Profile

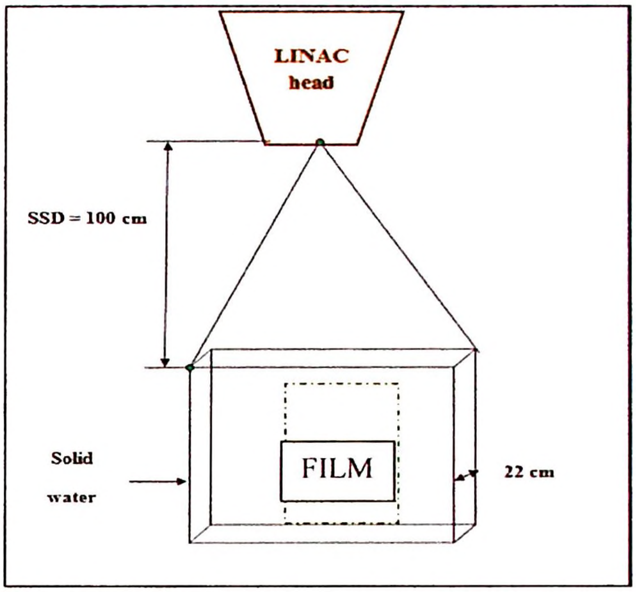

Figure 3.2.2 : The setup to measure the Percentage Depth Dose in 6 MV, 10 MV, 6 MeV and 9 MeV Beam

For 6 MV and 10 MV photon beam, the GafChromic EBT 2 film with size 25.5 cm x 20.5 cm and for 25.5 cm x 25.5 cm GafChromic RTQA film were used. However, GafChromic EBT 2 film with size 12.75 cm x 20.5 cm and GafChromic RTQA film with size 12.75 cm x 12.75 cm were used for 6 MeV and 9 MeV electron beam. Both films were exposed sandwiched in solid water phantom 30 cm x 30 cm x 30 cm with 400 MU at 0^0 gantry. All films were scanned after 24 hr after irradiated.

3.2.3 Percentage Depth Dose using Ionization Chamber

The water was filled into the water tank that was put on the treatment couch of linear accelerator. The farmer-type cylindrical chamber was inserted into the chamber holder. The cylindrical chamber was connected directly to the electrometer. Switch on the light field and the phantom was adjusted until the light field's cross hair is at the center of cylindrical cavity volume. The height of water phantom was adjusted to Source to Surface Distance (SSD) 100cm. The chamber was adjusted so that the reference point of the chamber is on the central axis of cavity volume. The chamber was lower into the water at reference depth, Z_{reff} of 5 cm from the water surface. The voltage of the electrometer was set at +200 V. The energy, field size, and monitor unit (MU) was set to be 6 MV, 10 x 10 cm^2 and 100 MU respectively. Turn on the beam and a few exposures was making until the readings are stable. The reading from the electrometer was recorded. Two readings each for full voltage positive polarity (+200V), full voltage negative polarity (-200V), half voltage positive polarity (+200V) and half voltage negative polarity (-200V) were obtain. The pressure and temperature in the treatment room were recorded using barometer and thermometer. Lower the farmer-type chamber to a depth of 10cm below the water surface. The energy, field size, SSD and MU was set at 6 MV, 10 x 10 cm^2, 100cm SSD and 100 MU. The polarity of electrometer was set at -200 V. Turn on the beam to start the exposure. The readings were recorded. The step was repeated by using Markus parallel- plate ionization chamber and measurement point was at 1 mm below the top of Markus's cap surface.