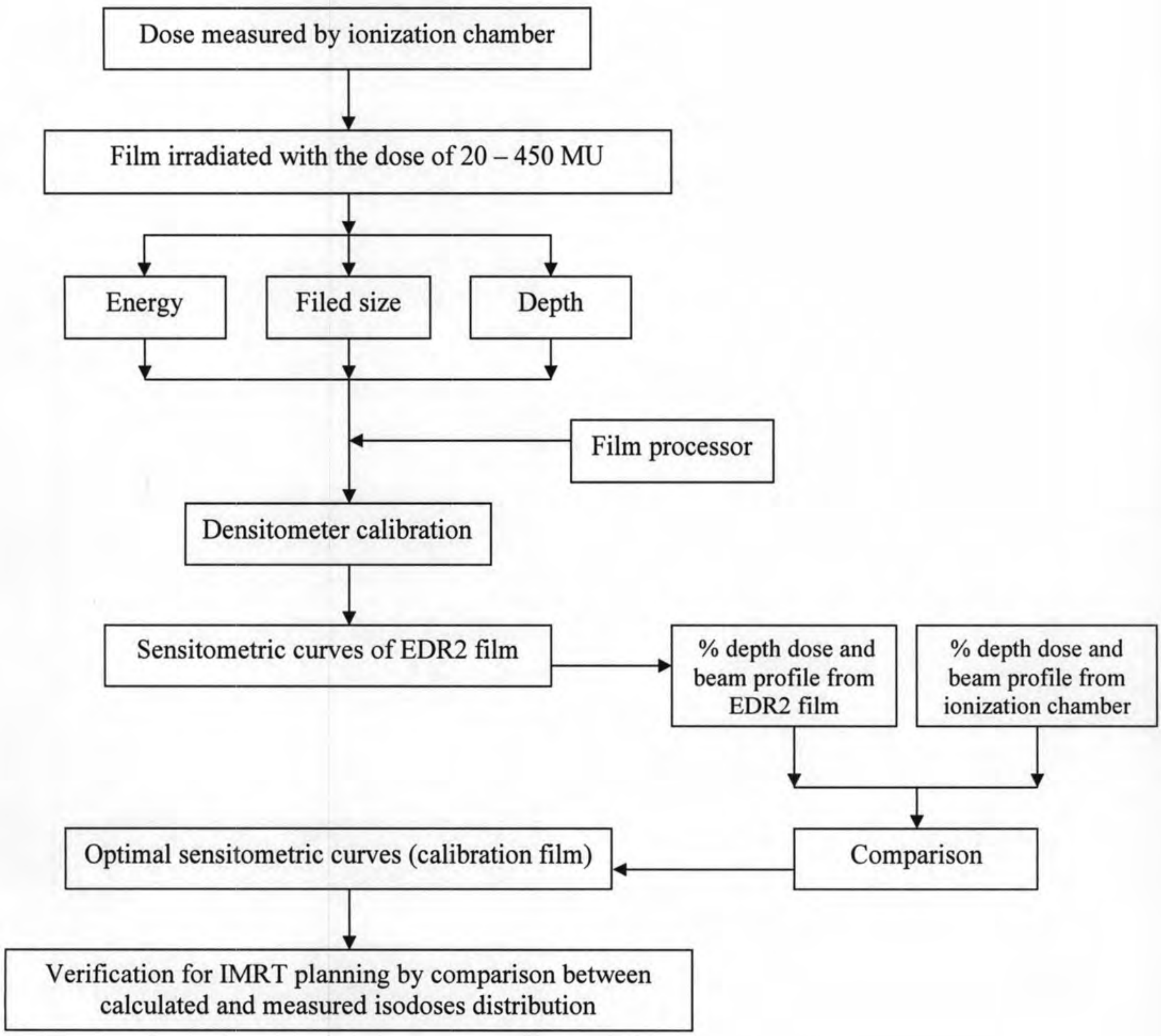
CHAPTER 3

RESEARCH METHODOLOGY

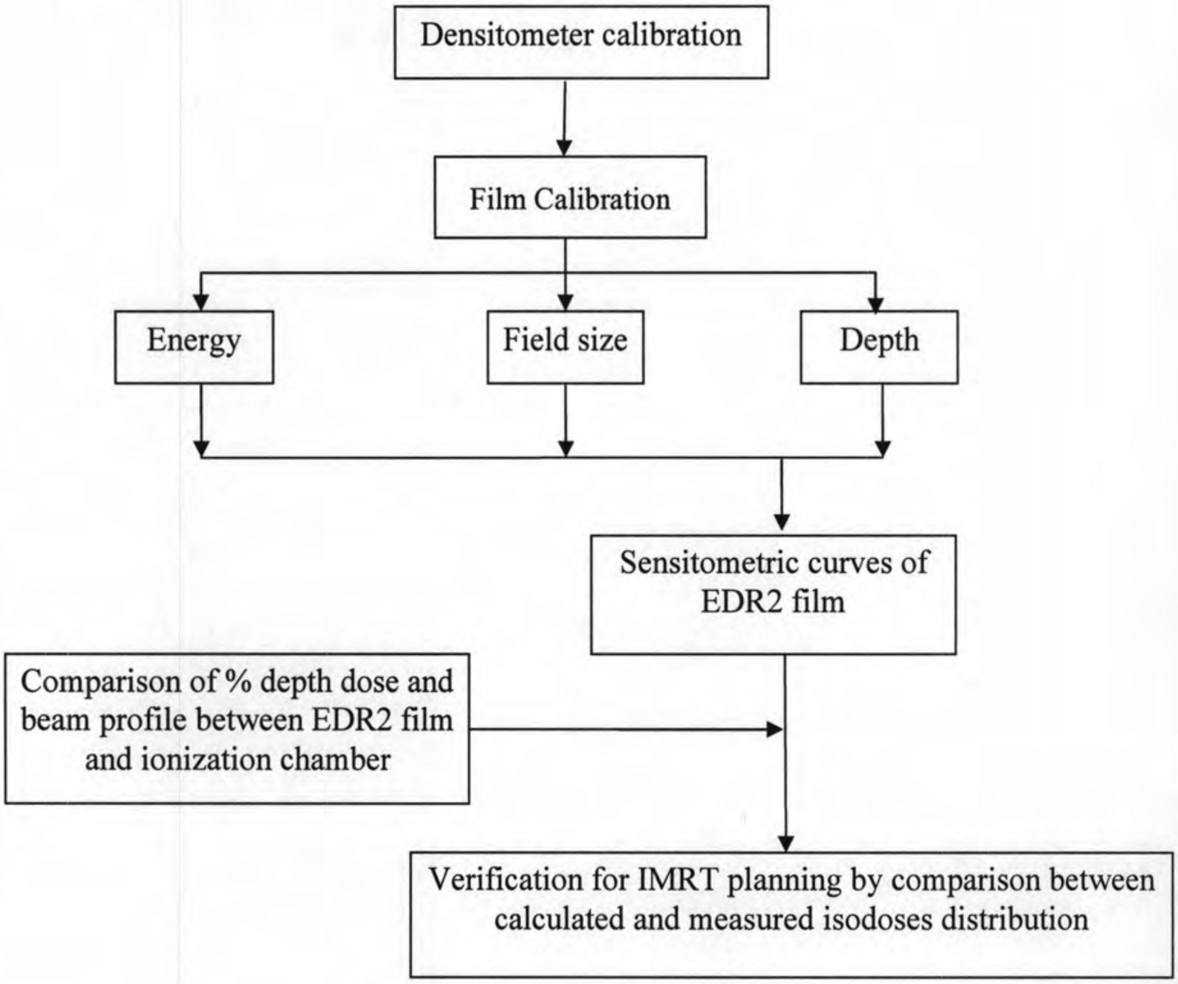
3.1 Research design

The study is the experimental study.

3.2 Research design model



3.3 Conceptual framework



3.4 Key word

- Film dosimetry
- EDR2 film
- Intensity modulated radiation therapy
- Sensitometric curve

3.5 Research questions

3.5.1 Primary question

How is the characteristic of EDR2 film with respect to energy, field size of the beam and the measurement depth?

3.5.2 Secondary question

Can the EDR2 film be used for verification of IMRT field?

3.6 Material

3.6.1 Linear accelerator

The Varian Clinac 23EX linear accelerator (Varian Oncology Systems, Palo Alto, CA, USA) gives dual photon beams of 6 MV and 15 MV, and six electron beam energies of 4, 6, 9, 12, 16 and 20 MeV. Photon field sizes are range from 0.5 x 0.5 cm^2 to 40 x 40 cm^2 at isocenter. The distance from the target to isocenter is 100 cm. These are six stationary therapy dose rates range from 100-600 monitor units per minute. The multileaf collimator (MLC) is mounted below the conventional collimator in the same direction of x-jaws. There are 120 leaves that can move as the dynamic movement. In this study, we performed with a nominal beam dose rate of 300 MU/min of 6 MV x-ray beam. The Varian Clinac 23EX is shown in Figure 3.1(a).

The Varian Clinac 21EX linear accelerator (Varian Oncology Systems, Palo Alto, CA, USA) gives dual photon beams of 6 MV and 10 MV, and five electron beam energies of 6, 9, 12, 16 and 20 MeV. Photon field sizes are range from 0.5 x 0.5 cm^2 to 40 x 40 cm^2 at isocenter. The distance from the target to isocenter is 100 cm. These are six stationary therapy dose rates range from 100-600 monitor units per minute. The multileaf collimator (MLC) is mounted below the conventional collimator in the same direction of x-jaws. There are 80 leaves that can move as the dynamic movement. In this study, we performed with a nominal beam dose rate of 300 MU/min of 10 MV x-ray beam. The Varian Clinac 21EX is shown in Figure 3.1(b).

(a) Varian Clinac 23EX (b) Varian Clinac 21EX

Figure 3.1 Linear accelerator with a dynamic multileaf collimator (DMLC)

3.6.2 The ready-pack EDR2 film

The film EDR2 (Eastman Kodak Co., Rochester, NY, USA) is shown in Figure 3.2, it is composed of cubic silver grains of approximately 0.24 μm diameter. The silver bromide coverage is approximately 2.3 g/m^2. The response curve of the EDR2 film is extending across a large range of radiation dose. This has been the reason for the term "extended dose range". The maximum light absorption in the film occur around 375 nm. The response of EDR2 film is almost linear over a wide range (from 25 cGy to 400 cGy), and it saturates at 600 cGy.

EDR2 film in ready pack comes in 50 sheet boxes and the size of 25.4 x 30.48 cm^2 was chosen for this study.

Figure 3.2 Kodak EDR2 verification Film

3.6.3 Vidar VXR-16 DosimetryPro film scanner

The Vidar film digitizer (VXR-16 pro dosimetry, Vidar systems Corp., Herndon, VA, USA) was used to scan the film. The film scanner operates with a resolution of 142 dots per inch (0.179 mm/pixel) and a depth of 16 bits, offers an optical density range of 0.04-3.65. Two-dimensional images are transferred to OmniPro™ IMRT (Scanditronix Wellhofer Dosimetric, Schwarzenbruck, Germany) software version 1.4.1.0 to read the optical density. Percent depth dose and beam profile are plotted by OmniPro Accept (Scanditronix Wellhofer Dosimetric, Schwarzenbruck, Germany) software version 6.4a. The Vidar VXR-16 DosimetryPro is shown in Figure 3.3.

Figure 3.3 The Vidar VXR-16 DosimetryPro

3.6.4 Ionization chamber

The CC13 ionization chamber 0.13 cm^3 (Wellhofer Dosimetrie, Schwarzenbruck, Germany) compact chambers can be measured absolute and relative dosimetry of photon and electron beams in radiotherapy and can be measured in solid phantoms or in water phantoms. The sensitivity of CC13 is 2.647 x 10^8 Gy/C. The CC13 ionization chamber is shown in Figure 3.4.

Figure 3.4 The CC13 ionization chamber
(http://www.scanditronix-wellhofer.com)

3.6.5 Electrometer

The DOSE-1 (Wellhofer Dosimetrie, Schwarzenbruck, Germany) is a high precision reference class electrometer that significantly exceeds the recommendations of the IEC 60731 and the AAPM ADCLs. It is suitable for the use with ionization chambers, semiconductors and diamond probes. The standard DOSE-1 connects to either TNC or BNC connector types. This electrometer is used with CC 13 ionization chamber and is set at 300 V. Maximum charge per pulse is approximate $\pm$ 40 nC/pulse. The DOSE-1 dosimeter is shown in Figure 3.5.

Figure 3.5 DOSE-1 electrometer
(http://www.depthdose.com/scanditronix_wellhofer.html)

3.6.6 Solid water phantom

The solid water phantom (MedTec, IA, USA) which the density of 1.03 g/cm^3, and atomic number of 5.97 is made in square slab of 30 x 30 cm^2 with the thickness of 0.2, 0.3, 0.5, 1.0, 2.0, 3.0, 4.0 and 5.0 cm. Solid water phantoms are shown in Figure 3.6.

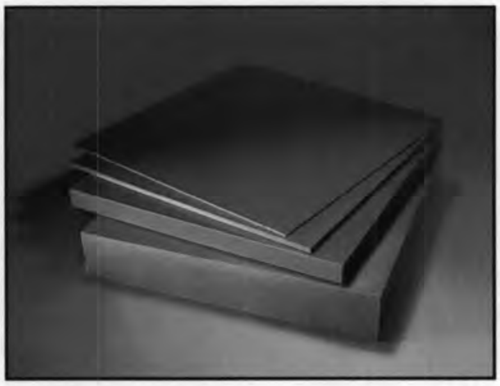


Figure 3.6 Solid water phantoms
(http://www.medtec.com)

3.6.7 Blue phantom 3D beam analyzing system

The blue phantom 3D beam analyzing system (Scanditronix Wellhofer Dosimetric, Schwarzenbruck, Germany) is made from acrylic plastic (perspex), having the scanning volume of 480 x 480 x 410 mm^3. It is prepared for external control from the OmniPro-Accept 6.4a software (IBA Advanced Radiotherapy, Scanditronix Wellhofer, Uppsala, Sweden). This phantom can be used for percent depth dose, beam profile with CC13 ionization chamber. The blue phantom is shown in Figure 3.7

The blue phantom 3D beam analyzing system comprises a three dimensional high precision servo mechanism and a perspex water tank. On the horizontal x-rail there is a sliding shoe on which detector holders are in all three dimensions for measuring both horizontal and vertical beams.

Figure 3.7 Blue phantom 3D beam analyzing system
(http://www.scanditronix-wellhofer.com)

3.6.8 Eclipse treatment planning software

Eclipse treatment planning software version 6.5 (Varian Oncology Systems, Palo Alto, CA, USA) is a treatment planning for all modalities such as 3D conformal, IMRT, electron, proton, and brachytherapy. Eclipse helps dosimetrists, physicists, and physicians efficiently create, select, and verify the best treatment plans for their patients. The Eclipse planning software is shown in Figure 3.8.

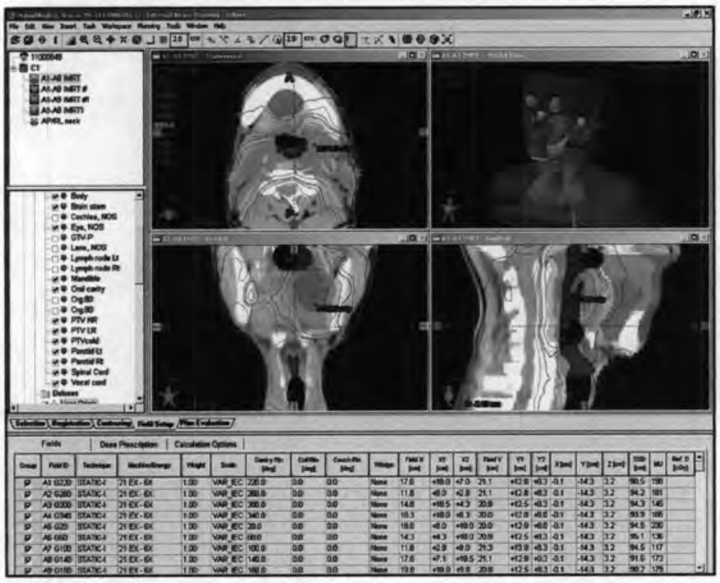


Figure 3.8 Eclipse planning software

3.6.9 Automatic film processor

The automatic film processor is Kodak *RP* X-OMAT Model M6B (Eastman Kodak Co., Rochester, NY, USA). The developer temperature is 34.8°C and during the course of processing, the temperature read out is within ± 0.3 °C. The time for whole process is about 90 seconds and this is usually not adjusted. The Kodak *RP* X-OMAT Model M6B is shown in Figure 3.9.

Figure 3.9 Kodak *RP* X-OMAT processor, Model M6B
(hptt://rsna2006.rsna.org)

3.7 Method

The experiment was performed by the following steps:

3.7.1 Film processing

The films that irradiated were processed by Kodak *RP* X-OMAT processor, Model M6B. Daily quality assurance of automatic film processor was performed in the morning before using. The process was mentioned in page 18 chapter 2. The optical density was read by a Vidar VXR-16 with the OmniPro IMRT software. The background and the exposed films were read by taking an average of the central region of 1 x 1 mm^2. The background (base plus fog) is the measurement of optical density of processed film, which has not been exposed to radiation. This value is subtracted form the optical density to get net optical density.

3.7.2 Densitometer calibration

The automatic film scanning densitometer of Vidar VXR-16 with the OmniPro IMRT software was calibrated to define the relation between the densitometer signal and net optical density by step wedge film. The special step wedge film was delivered from the manufacture with the range optical density of 0.04 to 3.65. An automatic scan was performed. The reference density value for each step of the step film was entered. The graph of the signal versus the net optical density was plotted.

3.7.3 Ionization chamber dose measurement

Radiation beams used were 6 MV x-ray from Varian Clinac 23EX and 10 MV x-ray from Varian Clinac 21EX. The doses delivered to solid water phantom were measured with 0.13 cm^3 ionization chamber. The ionization chamber was inserted in the middle of a custom drilled 2 cm thick slap and placed at 100 cm source surface distance (SSD) with 20 cm solid water phantom backscatter layers. The gantry was 0 degree, as shown in Figure 3.10. Ionization chamber readings were corrected for temperature and pressure. The absorbed doses were determined by IAEA TRS 398 protocol. The absorbed doses were checked for monitor unit given of 20, 50, 100, 200, 300 and 450 at field sizes 2x2 cm^2, 3x3 cm^2, 10x10 cm^2 and 15x15 cm^2 of 5 cm, 10 cm, and 15 cm depths for 6 MV and 10 MV x-ray beams. These data were used to calculate monitor unit required for the dose irradiated to the film.

Figure 3.10 Solid water phantom used for dose measurements with ionization chamber

3.7.4 Film irradiation

The EDR2 films were irradiated in solid water phantom with an overall size of 30 x 30 cm^2 on the linear accelerator couch, the films were placed at 100 cm SAD, sandwiched firmly between solid water phantom slaps, with 20 cm solid water backscatter layers. The EDR2 film were oriented normal to the beam central axis, with the irradiation of dose ranged from 20-450 cGy at 2x2 cm^2, 3x3 cm^2, 10x10 cm^2 and 15x15 cm^2 field sizes of 5 cm, 10 cm, and 15 cm depths, as shown in Figure 3.11. The effect of film processor was investigated by irradiating reference film of 10x10 cm^2 field size, depth of dose maximum (d_{max}), 100 cm SAD and 100 MU, and a film with the dose 20 cGy, 50 cGy, 100 cGy, 200 cGy, 300 cGy and 450 cGy of 3x3 cm^2 field size, depth of maximum and 100 cm SAD.

Figure 3.11 Solid water phantom used for dose measurements with EDR2 film

3.7.5 Construction of sensitometric curve

The optical densities along the central axis were measured using the film scanner which was Vidar VXR-16 with the OmniPro IMRT software. The net optical densities were obtained by subtracting the optical density corresponding to base and fog. Sensitometric curves were plotted as a function of net optical density versus dose for the set of fixed depth and varied field sizes and the set of fixed field size and varied depths for each energy studied.

3.7.6 Depth dose and beam profile measurement

A). Measured by ionization chamber

Depth doses were measured in water phantom scanner (blue phantom) with 0.13 cm^3 ionization chamber volume of using OmniPro Accept software for 2x2 cm^2 and 10x10 cm^2, the beam profiles and percent depth dose were scanned for 2x2 cm^2 and 10x10 cm^2 at 5 cm depth for 6 and 10 MV x-ray beams. The set up of water phantom is shown in Figure 3.12.

Figure 3.12 Blue phantom with 0.13 cm^2 ionization chamber for depth dose and beam profile measurement

B). Measured by EDR2 film

Depth doses and beam profiles were measured by films in solid water phantom. The film were placed at four levels between the slabs of solid water phantom, at d_{max}, 5 cm, 10 cm, 15 cm depths, as shown in Figure 3.13.

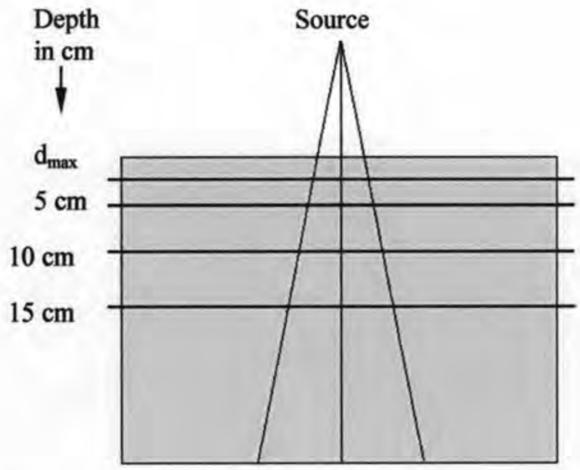


Figure 3.13 Solid water phantom used for depth dose and beam profile measurement by EDR2 film

It was assumed that the attenuation of the beam by the film was negligible. The central axis of the beam was perpendicular to the surface of phantom and passes through the center of the films, this set up was applied for all field sizes.

The beam profiles were plotted by normalized dose at the off axis points to the dose at central axis. The percent depth doses were read at 5, 10 and 15 cm depths. Then the beam profiles at 5 cm and percent depth doses from ionization chamber measurement were compared with the beam profiles and percent depth doses from film measurement.

3.7.7 Verification for clinical IMRT plan

After analyzing the data for the dependence of EDR2 film on field size and depth, the optimal field size and depth were obtained for each energy and being used as a calibration curve to transfer the optical density to dose. The idea is to irradiate a single film with many doses used for IMRT plan at one definite field size and depth. This calibration curve will be performed for each set of IMRT plan verification. Two IMRT plans in each energies were chosen for verification in solid water phantom. EDR2 films were placed at optimal depth in solid water phantom in a plane perpendicular to the incident beam. Then absolute isodose distribution in each plan is compared with the calculated isodose distribution from Eclipse treatment planning using OmniPro IMRT software.

3.8 Measurement

Variable : Independent variable = Energy, depth, field size
: Dependent variable = Optical density, dose

3.9 Data collection

The measured optical density from EDR2 films and the corresponding doses are prepared to plotted as the characteristic curve in Microsoft Excel program and the normalized dose in a 5 cm depth were plotted as a beam profile by OmniPro Accept software. The percent depth doses from OmniPro Accept software were tabulated.

3.10 Data analysis

The sensitometric curves are plotted between optical density and dose for a set of fixed depth, varied field size and a set of fixed field size, varied depth. The profile from ionization chamber measurement is compared with the profile from film measurement.

To use the film for verification of IMRT plan for the agreement between calculated and measured dose distributions, the gamma parameter has been adopted, as generally accepted the reference values for the agreement are 3% of dose and 3 mm of distance. The software includes the gamma evaluation analysis of the result.

3.11 Benefit of the study

- Determine the characteristic curves of EDR2 film.
- Determine the optimal parameters for film calibration.
- Used EDR2 film for absolute dose distribution verification of IMRT pretreatment planning.

3.12 Ethic consideration

This study was performed on the phantom. However, the ethical was approved by the Ethics Committee, Faculty of Medicine, Chulalongkorn University.