Radiochromic film dosimetry for linac-based stereotactic radiosurgery

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ABSTRACT
In linac-based stereotactic radiosurgery, assuring the quality of the planning and delivery of external photon beam requires accurate evaluation of beam parameters, usually including output factors, tissue-phantom ratio and off-axis ratios, and measurement of actual dose distributions from simulated treatment. We're going to test the use of calibrated radiochromic film (Gafchromic film; type MD-55, Nuclear associate) using a Lumiscan 75 digitizer to measure absolute dose and relative dose distributions for linac-based radiosurgery unit Relative dose distribution of a human-style spherical acryl phantom were measured using radiochromic film and calculated by treatment planning system. The absolute dose at the sphere center was measured by radiochromic film and micro chamber (Exradin A-14,0.009cc). What we want to demonstrate in this work, the 'well selected' radiochromic films when external photon beam are used in linac-based stereotactic radiosurgery are very accurate detector for dosimetry.

Keywords: Radiochromic film, Stereotactic Radiosurgery, Absolute dose, Relative dose.

1. INTRODUCTION
Radiochromic films have been developed for the measurement and mapping of absorbed radiation dose from photon and particle radiation sources. The use of radiation plays an important role in the diagnosis and treatment of disease, and radiation dosimetry is the tool providing the quantitative baseline against which the biological, chemical and physical effects of radiation can be assessed. As applied to medicine, radiation dosimetry has two principal aspects: quantifying the beam, or radiation field emanating from the radiation source; and quantifying the energy deposition within a volume of tissue, or other matter. In dealing with three-dimensional bodies, medical radiation dosimetry is involved with the mapping of radiation fields and absorbed dose as much, or more, than with spot measurement. Thus, by its very nature, its thinness, its flexibility, its tissue equivalence and its ability to be cut and shaped to any size, a Gafchromic radiochromic film dosimeter provides an excellent tool for measuring radiation fields and dose distribution. Linac based radiosurgery in general refers to the delivery of a high single dose of radiation to a small volume of tissue within the sensitive brain[1]. As in all radiotherapy techniques, tests are needed to verify the correct delivery of dose. Measurements of the dose distribution, required for design and accurate dose calculation of radiosurgery units, have been difficult due to the usual large detector size relative to the small radiation field. This study describes the use of radiochromic film (Gafchromic film ;type MD-55, Nuclear associate), to measure radiosurgery doses. High spatial resolution[2], relative insensitivity to variations in a radiation beam energy, near tissue equivalence makes it ideal for measuring steep dose gradients. Application of this film for measuring dose in small radiation fields[3], and at tissue interfaces[4] is well documented. The radiochromic film is nearly colorless before irradiation, turning an increasingly darker blue with increase dose. No physical, chemical or thermal processing is required and image becomes relatively stable within 24 hours post-irradiation [2].

2. MATERIALS AND METHODS
2.1. Lumiscan 75 digitizer (He-Ne Laser)
The scanning laser digitizer (Lumiscan 75 laser digitizer, Lumisys Inc., Sunnyvale, CA) is designed to scan film and directly measure optical densities up to 3.500 with a density resolution of 0.001. The measurement noise is less and 0.01 at an optical density of 2.5. This is accomplished with a spot of light derived from a helium–neon laser (632.8 nm, 0.1mm spot size) that is scanned across the film plane as the film is moved perpendicular to the laser scan. The system can digitize films ranging from 5"x7" to 14"x28" at a maximum resolution of 0.099 mm^2 and at a scan line capture rate of 115 lines/second.

2.2. Radiochromic film
The Radiochromic film used in this study was Gafchromic dosimetry media, type MD-55, model No.37-041 provided by Nuclear Associates. The films were delivered in the form of 13 x 13 cm^2 sheets sealed in black light-tight envelopes.

The Gafchromic film MD-55 is designed for the measurement of absorbed dose of high-energy photons. In this regard, the response of the film is energy-independent for photons above about 0.2MeV. The structure of Gafchromic film MD-55 is shown in Figure 1.

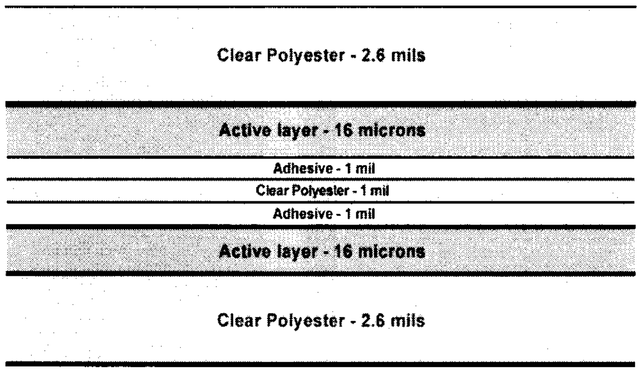

Fig. 1 Configuration of GAFCHROMIC dosimetry film ;. MD-55

2.3. Radiochromic dosimetry

Two 13 x 13 cm^2 sheets of Gafchromic film MD-55 to measure the dose were carefully cut and marks placed near the corner, One film was used for the calibration (each of size 1.5 x 1.5 cm^2), the other film was used for measurement of the depth dose and dose distribution for radiosurgery dosimetry. All measurements were performed with a Siemens M6740 using 6MV photon beam and evaluation of all films was performed 24h after irradiation, as recommended by McLaughlin *et al* (1991). The Gafchromic film was sandwiched in between the polystyrene solid phantom slices to measure at 5cm depth. The calibration results were achieved by irradiating the films in 4Gy intervals from 0-112Gy using a 10 x 10 cm^2 filed size 100cm SSD. For the measurement of depth dose profile, a film slice (3 x 13 cm^2) was placed in the center of the field (10 x 10 cm^2) at 100cm SSD and irradiate in does 30Gy. To verify the accuracy of the prescribed dose delivery to a target isocenter point using five beams set up, which is calculated by Linapel radiosurgery planning system we measure the absolute dose and relative dose distribution using micro-chamber or Gafchromic film. Micro-chamber and Gafchromic film was placed into the human-style acryl phantom and irradiated in 3Gy per each 1 arc beam. All irradiated films were digitized with Lumiscan 75 laser digitizer and processed with the RIT 113 film dosimetry system (RIT Inc., Denver, Colorado)

3. RESULTS AND DISCUSSIONS

3.1 Film Calibration

The calibration results are shown in Fig.2. The curve has been fit to second-degree polynomial for converting measured optical density to dose.

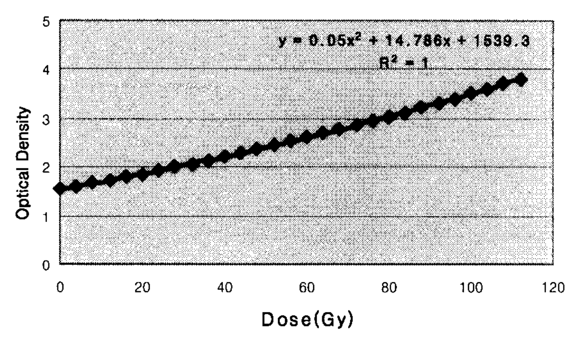

Fig. 2 Calibration curve (Optical density vs. radiation dose) For Gafchromic film MD-55

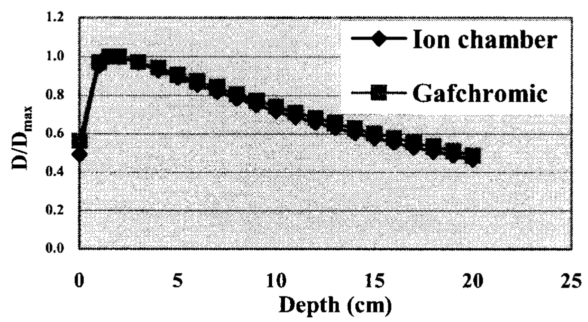

Fig. 3 Depth dose for a 6MV photon filed with Ionchamber and Gafchromic film (field size:10x10cm^2, 100cmSSD)

3.2 Radiochromic dosimetry

3.2.1. Absolute Dose Evaluation

In Fig.3 the depth dose curve using Radiochromic film in polystyrene solid phantom is plotted and compared to ion chamber in water and same solid phantom. It is easily seen that the maximum dose are at a depth of 15mm in all measurements. The absorbed dose, as computed by the Linapel treatment planning system, is measured at the target isocenter, which is the center place of the human style acryl phantom, with micro chamber and Gafchromic film. The results are shown in table.1. The comparison presented in table.1 demonstrates that the absolute dose delivered to the target isocenter point was close to the prescribed dose within accuracy of radiochromic film dosimetry (±5).

3.2.2. Relative Dose distribution

Fig. 4 shows the planned and measured isodose distributions in transverse plane. The measured diameters of the 90%, 50%, and 30% is dose lines agree with the calculated values (Fig.4a) The uncertainty of the film measurements increases from ±1 mm for the 90% isodose line to about ±5 mm for the 30% line.

Table.1 Absolute dose Measurement (Gafchromic film MD-55 and micro chamber) and treatment planning calculation (Linapel radiosurgery planning system), 5 arc beam, 20mm cone, 1500cGy at isocenter.

Arc	Dose_Meas		Dose_Presc	Error(%)	
	Ionchamber	Gafchromic film		Ion/Presc	Film/Presc
1	299.35	290.78	300	-0.2	-3.1
2	298.48	293.71	300	-0.5	-2.3
3	300.21	296.2	300	0.07	-1.3
4	300.18	289.36	300	0.06	-3.5
5	300.32	285.41	300	0.1	-4.8

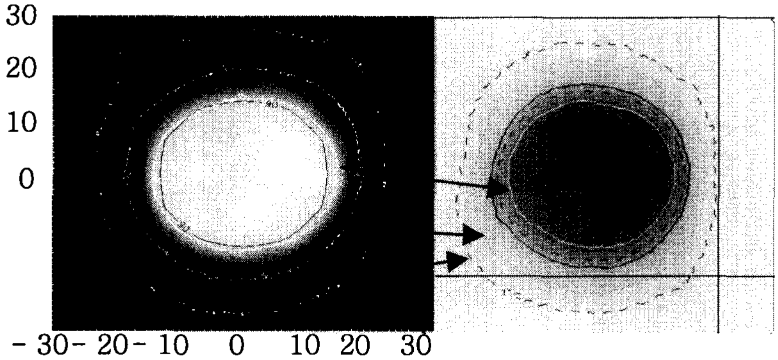

Fig.4a Fig. 4b

Fig. 4 Relative dose distribution curves, (4a) Comparison of calculated isodoses for radiosurgery treatment with those measured using Gafchromic film MD-55 in a human style acrylic phantom irradiated to a dose 15Gy. (4b) Measured isodose curve which processed with the RIT 113 film dosimetry system.

4. CONCLUSIONS

This results show that absolute dose and relative dose distribution curves obtained with Gafiochromic film can provide the information of value for acceptance testing and quality control of dose measurement and calculation. It is concluded that the radiochromic film, with some limitations, is a convenient and useful dosimetry tool for linac-based radiosurgery

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