Evaluation of the Radiochromic Film Dosimetry for a Small Curved Interface

Sei-Kwon Kang, Soah Park, Taejin Hwang, Kwang-Ho Cheong, Taejin Han, Haeyoung Kim, Me-Yeon Lee, Kyoung Ju Kim, Hoonsik Bae

Department of Radiation Oncology, Hallym University College of Medicine, Seoul, Korea

A tumor on the eyelid is often treated using a high-energy electron beam, with a metallic eye shield inserted between the eyelid and the eyeball to preserve the patient's sight. Pretreatment quality assurance of the inner eyelid dose on the metallic shield requires a very small dosimetry tool. For enhanced accuracy, a flexible device fitting the curved interface between the eyelid and the shield is also required. The radiochromic film is the best candidate for this device. To measure the doses along the curved interface and small area, a 3-mm-wide strip of EBT2 film was inserted between the phantom eyelid and the shield. After irradiation with 6 MeV electron beams, the film was evaluated for the dose profile. An acrylic eye shield of the same size as the real eye shield was machined, and CT images free from metal artifacts were obtained. Monte Carlo simulation was performed on the CT images, taking into account eye shield material, such as tungsten, aluminum, and steel. The film-based interface dose distribution agreed with the MC calculation within 2.1%. In the small (millimeter scale) and curved region, radiochromic film dosimetry promises a satisfactory result with easy handling.

Key Words: Radiochromic films, Monte Carlo calculation, Small field, Interface dose

INTRODUCTION

For an eyelid MALT lymphoma, 25～30 Gy electron radiation treatment is usually prescribed, in which a metallic eye shield is routinely used to protect the critical optesthesia-related organs, including the lens.[1-4] The metallic shield is inserted between the eyelid and the globe, and the inner eyelid dose usually merits interest. In clinics, pretreatment quality assurance (QA) for the prescribed radiation dose is a necessity. However, dosimetry devices like MOSFET and TLD are too large for dose measurement at the interface between the eyelid and the shield. Therefore, while the skin dose on the eyelid is usually checked, the inner eyelid dose remains uncertain.

Film dosimetry is valuable in medical applications, enabling two-dimensional dose evaluation with a single exposure at a better resolution.[5] Also, the film can be cut into a smaller size for application in a small area where other dosimetry tools cannot be employed due to their size. Its nearly negligible thickness is another advantage. The film has characteristics that other devices do not possess, which make it best suited for dose evaluation of a small curved interface. This short paper presents the usefulness of film measurements for an interface dose in a small curved region. Monte Carlo calculation was performed to confirm the film results.

MATERIALS AND METHODS

A curved tungsten shield with a 19.1-mm outer radius and 2-mm thickness (Radiation Products Design, Inc., MN, USA) was used for this experiment (Fig. 1a). The shield consisted of a stainless steel knob, a tungsten (W) body, and a 0.5-mm-thick aluminum hemispherical shell around the body. The shield was placed on solid water and covered with a 3-mm-thick thermoplastic sheet to simulate an eyelid (Fig. 1b). For radiation exposure, a 3-mm-wide strip of EBT2 film (International Specialty Products, Wayne, NJ, USA) was inserted between the shield and the eyelid simulator. The source-to-steel knob distance (SSD) was set at 100 cm, and

Submitted November, 19, 2012, Accepted November, 28, 2012
Corresponding Author: Soah Park, Department of Radiation Oncology, Kangnam Sacred Heart Hospital, 1, Shingil-ro, Yeongdeungpo-gu, Seoul 150-950, Korea
Tel: 02)829-5654, Fax: 02)833-2839
E-mail: sophia@hallym.or.kr

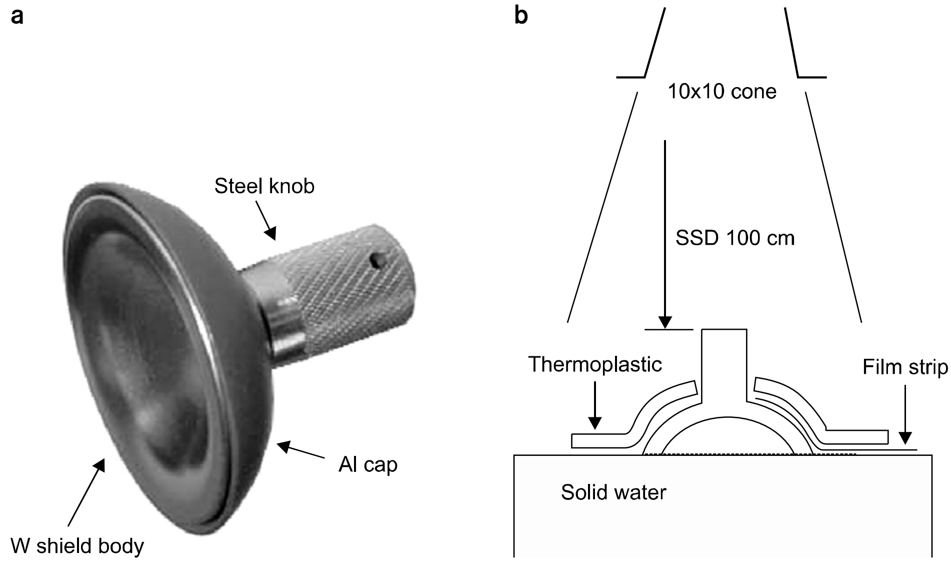

Fig. 1. (a) A metallic eye shield consisting of a tungsten (W) body, an aluminum (Al) cap, and a stainless steel knob. The Al cap is intended to reduce backscattered radiation. In a clinic, this shield is inserted between the eyelid and the eyeball. (b) The irradiation setup. An EBT2 film strip was inserted between the curved metal shield and the overlying thermoplastic phantom eyelid.

the field size was defined as 10×10 cm^2 using an electron applicator for the eyelid phantom irradiation. A 6-MeV electron beam at 200 monitor units (MU) was delivered using a Varian 21EX linear accelerator. The optical density map for the film was created up to 2.5 Gy using 3×3 cm^2 films, in which the dose calibrations were based on a Farmer-type ionization chamber. The film was attached to the transparent film and scanned with a VXR-16 film digitizer (VIDAR Systems Corporation, Herndon, VA, USA). The resulting images were processed using DoseLab, a freeware for film dosimetry.[6] Flat-bed scanners are most commonly recommended imagers for the film, however, since the freeware DoseLab was based on the VIDAR data, the VIDAR scanner was used for the data processing. No meaningful dose changes were observed between those of VIDAR and flat-bed scanner results. Since the VXR-16 digitizer had no option of channel splitting like red, green and blue, gray intensity was used. The film scanning resolution was 71 dpi.

To confirm the film results, MC simulation was performed using the CT images. To this end, the EGSnrc-based BEAMnrc and DOSXYZnrc were commissioned for the linear accelerator.[7,8] For the 6 MeV electron beam, the calculated R_{50} and R_p (electron practical range) agreed respectively with those of the measured percentage depth doses (PDD) to within 1 mm with the starting modeling energy of 6.72 MeV. Using a CT image in the MC calculation requires CT eye shield images free from metal artifacts. To acquire CT images without metal artifacts, an acrylic shield of the same size was machined and replaced during a CT scan. The slice thickness was 1.25 mm. An intermediate step is required during which the proper material for the MC calculation is considered. Because the CT numbers for the eyelid simulator and the machined acrylic shield were similar, the identification of each part was not possible. Therefore, each region corresponding to the aluminum cover, steel knob, and tungsten shield body was modified respectively into discernible ranges from each other. Then, via "ctcreate," a utility in the MC package, the CT images, including their specific material information and densities, were converted into the DOSXYZnrc image input format. The MC calculation results were reported as absolute doses using the reference condition simulation.

RESULTS AND DISCUSSION

Fig. 2 shows the dose-converted film strip images, in which the colored distributions show an increased dose from blue to red. The extracted profile from the third film strip along the white arrowed line is also shown. The dose profiles for each of the three strips were aligned and averaged. The alignment of the extracted profiles was not difficult to average because the profiles showed common features at specific points, and the alignment uncertainty was less than 1 mm. The standard

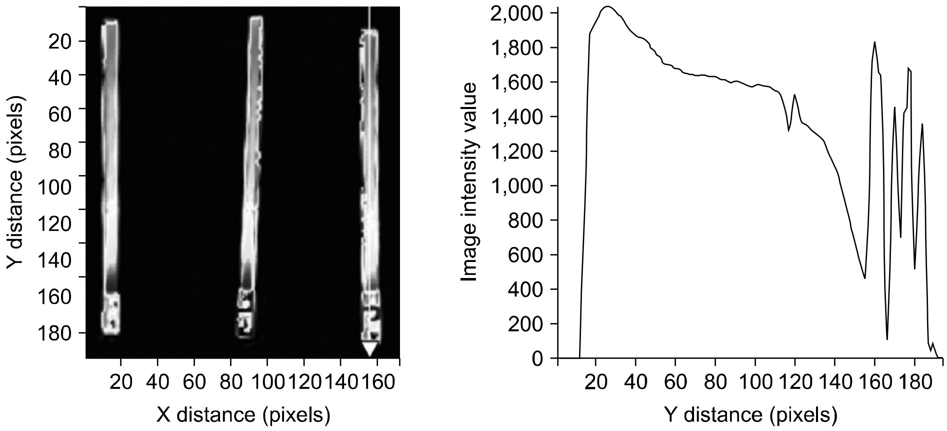

Fig. 2. Converted dose value images of the three film strips (left). The regions in red had covered the metallic shield. Along the white arrowed line on the third strip, the dose profile is displayed (right). The units on the x and y axes represent the pixel number and image intensity, respectively.

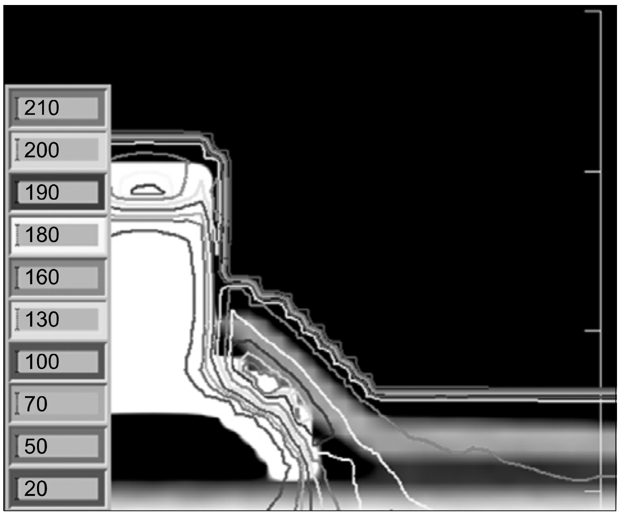

Fig. 3. Monte Carlo calculation results taking into consideration the material information on W, Al, and steel. The inner eyelid doses are at least above 180 cGy.

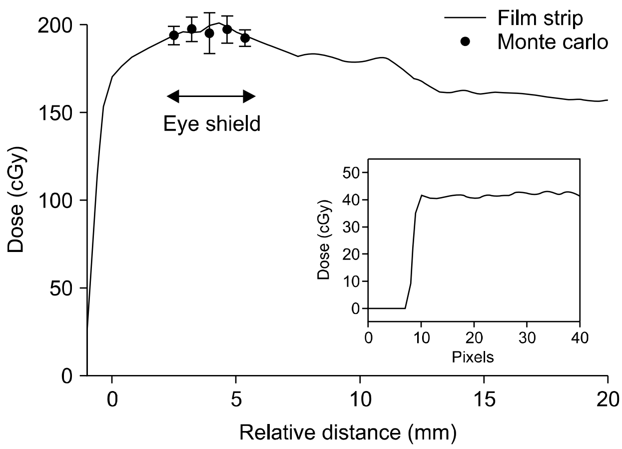

Fig. 4. Comparison of the film-based dose profile and the ROI-based MC simulation results. Despite the relatively large standard errors, the MC calculation agreed with the film strip measurements within 2.1%. The inset is the edge profile from irradiated film, which shows no possible additional side scatter from the scanner light.

deviation for the aligned three profiles was less than 1% in the eye shield cover range.

The MC simulation result is shown in Fig. 3. Overall, the inner eyelid dose ranged from 180～200 cGy at the interface with the metallic eye shield. The sub-mm dimension in this calculation encourages the adoption of the film measurements to compare the results. Since the film strips were positioned between the shield and the eyelid simulator, and the two materials in contact had vastly different densities, a selection had to be made regarding the depth at which each material should be considered for the interface dose. Here, five small ROIs extending 1 mm into each material from the central boundary were drawn along the curved interface, and point doses were obtained with the standard deviation.

The resulting MC point doses were overlaid onto the averaged film dose profile, as shown in Fig. 4. The MC simulation data points were at uncertain positions, but these were less than 1 mm. The MC calculation results had relatively large error bars, which came from the ROIs containing both tungsten (and aluminum) and thermal plastic doses. However, the film and MC calculation results showed a large agreement in average values within 2.1%, reflecting the usefulness of film dosimetry for such a curved interfacial area, which other dosimetry tools cannot access with ease. In this result, the probable uncertainty in the film measurement from the air gap was assumed to be negligible, thus neglected in the consideration. One possible concern of using the small width film is that the scanner light can disturb the film strip reading, resulting overdose from the side scatter. The inset in the Fig. 4 is the one example of the film profile exposed by 40 cGy. The film edge shows no side scatter peak except the usual pixel by pixel fluctuation. The narrow width of the film strip can be used successfully without the side scatter from the scanner light.

It is notable that film dosimetry and MC simulation were successfully employed for the interface dose distribution between materials of extremely different densities: tungsten and thermal plastics. The application of the radiochromic film in small fields with sub-cm dimensions has been successfully executed before,[9,10] and in these previous studies, the film results were regarded as the gold standard for other dosimetry modalities because of their high resolution. In this report, we extended the film measurements to the interface dosimetry for a small and curved area. The microMOSFET (TN RDM 502, Thomson and Nielsen, Ottawa, Canada) can be an alternative for the interface point dose in a small, curved region.[11] Nevertheless, its size of 1×1 mm and length of 3.5 mm cannot be neglected. Another cumbersome issue is its dose dependency on the relative direction of the incoming radiation, thus requiring correction of the directional dependency for exact evaluation. In this respect, the film is the top choice, enabling two-dimensional evaluation even in the curved region.

CONCLUSION

This paper aimed to show the usefulness of film dosimetry for dose distribution in the small, millimeter-size curved interface between the metallic shield and the covering eyelid. For this unusual environment, radiochromic film strips were used, and the results were confirmed by MC simulation. The thin and flexible film occupies negligible space and thus is the optimal dosimetric tool for the small and irregular space.

REFERENCES

1. **Shiu AS, Tung SS, Gastorf RJ, Hogstrom KR, Morrison WH, Peters LJ**: Dosimetric evaluation of lead and tungsten eye shields in electron beam treatment. Int J Radiat Oncol Biol Phys 35:599-604 (1996)
2. **Weaver RD, Gerbi BJ, Dusenbery KE**: Evaluation of eye shields made of tungsten and aluminum in high-energy electron beams. Int J Radiat Oncol Biol Phys 41:233-237 (1998)
3. **Zhou P, Ng AK, Silver B, Li S, Hua L, Mauch PM**: Radiation therapy for orbital lymphoma Int J Radiat Oncol Biol Phys 63:866-871 (2005)
4. **Yamashita H, Nakagawa K, Asari T, Murakami N, Igaki H, Ohtomo K**: Radiotherapy for 41 patients with stages I and II MALT lymphoma: a retrospective study. Radiother Oncol 87: 412-417 (2008)
5. **Soares CG**: Radiochromic film dosimetry. Radiat Meas 41: S100-S116 (2007)
6. **Childress NL, Vantreese R., Kendall R**: DoseLab v.4.0.0: dose comparison software package for medical physics. The University of Texas M.D. Anderson Cancer Center, Houston (2004)
7. **Rogers DW, Faddegon BA, Ding GX, Ma CM, We J, Mackie TR**: BEAM: a Monte Carlo code to simulate radiotherapy treatment units. Med Phys 22:503-524 (1995)
8. **Kawrakow I**: Accurate condensed history Monte Carlo simulation of electron transport. I. EGSnrc, the new EGS4 version. Med Phys 27:485-498 (2000)
9. **Lee KY, Fung KKL, Kwok CS**: Application of high-resolution radiochromic film dosimetry in verifying a small-field stereotactic radiosurgery plan. Appl Radiat Isotopes 64:934-939 (2006)
10. **Wong CJ, Ackerly T, He C, et al**: Small field size dose-profile measurements using gel dosimeters, gafchromic films and micro-thermoluminescent dosimeters. Radiat Meas 44:249-256 (2009)
11. **Ramaseshan R, Kohli KS, Zhang TJ, et al**: Performance characteristics of a micro MOSFET as an in vivo dosimeter in radiation therapy. Phys Med Biol 49:4031-4048 (2004)

휘어진 경계에서의 좁은 영역에 대한 Radiochromic 필름 도시메트리 평가

한림대학교 의과대학 방사선종양학교실

강세권 · 박소아 · 황태진 · 정광호 · 한태진 · 김해영 · 이미연 · 김경주 · 배훈식

눈꺼풀에 발생한 종양의 치료를 위해서는 종종 고에너지 전자선이 이용되며, 이 경우 환자의 시력 보호를 위해 금속차폐체를 눈꺼풀과 안구 사이에 삽입하고 방사선 치료를 시행한다. 차폐체에 접한 눈꺼풀 안쪽의 방사선량 확인을 위해서는 매우 작은 측정도구가 필요하며, 굽은 경계면의 특성상 유연한 측정도구가 바람직한데, radiochromic 필름 도시메트리는 이 목적에 매우 적합하다. 작으면서도 휘어진 경계면을 따라서 선량을 측정하기 위해, 눈꺼풀 팬텀과 차폐체 사이에 3-mm 폭의 EBT2 필름 띠를 삽입하고, 6MeV의 전자선을 조사 후, 선량분포를 얻었다. 금속차폐체와 동일한 크기로 아크릴 재질의 차폐체를 제작하여, 금속인공영상물이 없는 CT 영상을 얻은 후, 이를 이용하여 몬테칼로 전산모사를 수행하였다. 전산모사에서는 실제 안구차폐체의 재질을 따라 텅스텐, 알루미늄 및 스테인레스 스틸 등의 물질 정보를 이용하였다. 이렇게 얻은 전산모사 결과는 필름 측정과 2.1% 내에서 일치하였다. 밀리미터 크기 정도로 작고 또한 휘어진 영역에서 radiochromic 필름 도시메트리는 취급도 용이할 뿐만 아니라 만족스런 정확도를 보여주고 있다.

중심단어: Radiochromic 필름, 몬테칼로 계산, 소조사면, 경계면 선량