Wiener Filter Used in the EBT2 Film for Radiation Therapy

Liyun Chang

Abstract—EBT2 film has been widely used in the dosimetry application of radiation therapy with lots of benefits especially its self-development, water equivalent, energy independent and high spatial resolution. However, the higher inhomogeneity between the pixels of EBT2 image, needed to be averaged out according to the traditional method, but it could sacrifice the spatial resolution. The Wiener filter technique was introduced in this paper. The EBT2 film was calibrated by using the PDD method and the film calculate doses were compared with the measurement doses by the edge detector with the water phantom. The results demonstrate that the Wiener filter technique has higher accuracy than the traditional method and it would not sacrifice the high spatial resolution of EBT2 film. This method can also be applied to all the quality assurances of treatment planning of radiationtherapy by using EBT2 film.

Index Terms—Wiener filter, EBT2 film, radiation therapy

I. INTRODUCTION

A rapid evolution of the available treatment methods has taken place in radiation therapy during the last two decades, which includes those precise treatment techniques: intensitymodulated(IMRT), stereotactic (SRT) radiotherapy and several dynamic techniques. In order to achieve dose distributions with highly conformal to the target volume and spare normal tissues (especially the organs at risk), the irregular fields and steep dose gradients are applied by the inverse treatment planning system with the advanced linear accelerator. For the effectiveness and success of the treatment prescribed, a high spatial and dosimetric accuracy during treatment delivery is of crucial importance. Therefore, particular quality assurance (QA) procedures have been developed together with those increasingly sophisticated treatment techniques [1]-[3], which would include the verification of absolute doses at one or more reference points as well as of twodimensional dose distributions in different planes in awater-equivalent phantom.

Those requirements could not be achieved by using the conventional dosimeters, such as ionization chambers, semiconductor detectors and thermoluminescent detectors (TLDs), since they could not offer high spatial resolution, twodimensional information and determination of absolute dosessimultaneously. Film dosimeters offer permanent records of the ionizing dose distribution measured at high resolutions with evident advantages for being 2D detectors. Due to the high-atomic-number material constituents, the traditional used silverhalide films, however, have the disadvantage of pronounced energy dependence [4], [5]. This could introduce systematic errors for most usual treatment plans [6], [7].

With good tissue equivalence, radiochromic films use a radiation-sensitive dye, organized into microcrystals and embedded in a gelatin binder, to measure the energy dose of ionizing radiations. However, typical fractional doses could not be measured with radio chronic detectors [8], EBT film, the product of International Specialty Products(ISP), which overcomes this limitations, has been widely used specifically to address the needs of the medical physicist and dosimetrist working in the radiotherapy environment [9]-[12]. Comparing with previous GAFCHROMIC® films, EBT film is self-developing, but it also incorporates numerous improvements. Some of these improvements include: the dose range extended to be 1cGy - 800cGy; it is ten times more sensitive than the GAFCHROMICHS film; it is energy independent from the keV into the MeV range; the post-exposure density growth is faster and lower; the temperature withstands up to 70°C. EBT film can be easily read by standard flatbed scanners and had a high degree of 2D spatial accuracy and uniformity of response [13]-[19].

Fig. 1. Configuration of EBT2 film.

EBT2 film is the next generation of EBT film. The configuration of EBT2 film was shown in Fig. 1. The active part of the film has been reduced to a single layer about 30μm and the topcoat is 175μm polyester substrate. EBT2 film uses exactly the same active component as EBT film, but improved at a number of features.

The new film contains a yellow marker dye that protects the active layer from exposure by UV and visible light and reduces the effect from these sources by several times [20] and the dye could cause minimal intra- and inter-sheet non-uniformity of the films. The coated layers of EBT film, which incorporates a natural gelatin, has been replaced with a synthetic polymer, which reportedly allows better control of the active layer composition, leading to minimal energy dependence [21], [22]. According to manufacturer, the main atomic composition of the overall composition of EBT2 film was listed in Table I and the effective atomic number of overall film, $Z_{eff}$, is calculated as around 6.8, which is nearly
TABLE I: THE MAINLY ATOMIC COMPOSITION OF THE OVERALL COMPOSITION OF EBT2 FILM (ATOMIC%) 

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<tr>
<td>%</td>
<td>40.9%</td>
<td>0.1%</td>
<td>42.4%</td>
<td>16.6%</td>
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However, the homogeneity of EBT2 film is still not that good [20], and is getting significant when the distance between the very near two pixels is getting smaller. The general method to reduce the effect of film inhomogeneity is averaging out a lot of pixels; however, it will be a trade-off between the spatial resolution and homogeneity.

Generally speaking, to get better homogeneity, an 8 × 8 mm² area of the film would be taken average for the any centered point[23], but it could sacrifice one of the advantages to utilize EBT2 film for the dosimetry purpose, that is, the high spatial resolution. To keep the high spatial resolution with good film homogeneity, a new algorithm was provided in this paper by filtering the film data with Wiener filter.

II. MATERIALS AND METHODS

Three 8"×10" EBT2 films from Lot No. A03171101B were used for this study. The film was scanned with 127 dpi (5 dots per mm) before irradiation (pre-scan), which is a good choice for spatial resolution on an Epson 10000XL scanner to generate the background tiff image [24]. The 6 MV photon beam of an Electa Synergy clinical linear accelerator was used for this investigation (Fig. 2).

The EBT2 film was taped to a 30×30×5 cm³ polystyrene plate and sandwich into the 30×30×30 cm³ polystyrene phantoms as the calibration steps using the PDD method [23]. 290 Monitor Units (MU) of the accelerator were given to each of the films and after that they were scanned again (post-scan) to get the film optical density for the dosimetry analysis, which was performed by Matlab (version 7.12) software. The pixel value was converted from the red channel of the pre-scan and post-scan films to net optical density, OD, which could be written as

$$OD = \log_{10}\left(\frac{PV_1}{PV_2}\right)$$

where $PV_1$ and $PV_2$ were the pixel value of the pre-scan film and the post-scan film, respectively.

The OD on the beam central axis at the depth 0.4 to 25.0 cm, with an interval of 0.2 cm, was chosen. In all, 124 OD points for each film were automatically extracted. The delivered dose versus the measured OD was then could be fitted by the general equation:

$$D_{\text{fitted dose}} = a_1 \times OD + a_2 \times OD^{a_3}$$

where $D_{\text{fitted dose}}$ is the fitted dose; $a_1$, $a_2$ and $a_3$ are fitting parameters. To make the fitting process smoothly, the net optical density and the delivered dose were normalized at depth 5 cm, and noted as $NOD$ and $ND$ respectively. The fitting process will be then changed to be

$$ND = a_1 \times NOD + a_2 \times NOD^{a_3}$$

where $a_1$, $a_2$ and $a_3$ are fitting parameters. The fitting process was repeated twice, the first time with $a_1$, $a_2$ and $a_3$ not bound, but after getting the fitted $a_3$ value, it was rounded to the nearest tenth for the second fitting process. Comparing (2) and (3), the relationship between the fitting parameter in (2) and (3), could be deduced to be that $a_3^* = a_3$, $a_1^* = a_1x$ (dose at 5 cm)/(net optical density at 5 cm) and $a_2^* = a_2x$ (dose at 5 cm)/(net optical density at 5 cm)

The Wiener filtering process used the function “wiener2 (ND, [M N], noise)” in Matlab. N-by-M was the chose neighborhood in the image of matrix ND. The Wiener filtered data will be compared with the original data (the data without filtering) and the data averaged with 8x8 mm² .

III. RESULTS AND DISCUSSIONS

According empirical experiences, the best choice of $M$, $N$ and noise would be 30, 30 and 1 respectively, but the filtered matrix should be times 30 to make it back to its original size. The fitting parameters for the three tested EBT2 film was shown in Table II. It is interested that the exponent item in (3) has different value of the third digit after the decimal point. It shows the inter-film discrepancies in the calibration equation.

The calibration results of the first film by (3) were shown in Fig. 3. The blue dashed curve is the normalized dose according to (3), transferred from the net optical density with 127 dpi, which is measured by edge detector in water phantom. That curve is similar to the noises bouncing around the curve of normalized delivered doses, which is the delivered dose normalized at depth 5 cm. Except at the depths of very beginning and very end (usually those are useless data
at the margins of the film), the curve of Wiener filtered and the 8x8 mm² averaged are fitted well with the normalized delivered dose. Through Fig. 4, the percentage differences between the normalized delivered doses and the calculated doses for them were also closed each other and within 1.5%.

TABLE II: THE FITTING PARAMETERS FOR THE THREE EBT2 FILMS BY (3)

<table>
<thead>
<tr>
<th>Film</th>
<th>a1</th>
<th>a2</th>
<th>a3</th>
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<tbody>
<tr>
<td>Film 1</td>
<td>0.5658</td>
<td>0.4322</td>
<td>1.8</td>
</tr>
<tr>
<td>Film 2</td>
<td>0.6855</td>
<td>0.3193</td>
<td>2.0</td>
</tr>
<tr>
<td>Film 3</td>
<td>0.5347</td>
<td>0.4776</td>
<td>1.7</td>
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Fig. 3. The calibration results of the first film

However, according to Fig. 5 and Fig. 6, the percentage differences of the original data with the original, averaged and filtered data for the second film would be higher than 5%.

Fig. 4. The percentage differences between the normalized delivered dose with the original, averaged and filtered data for the first film

IV. CONCLUSION

A Weiner filter technique was presented and applied in the dosimetry systems of EBT2 film. It was shown to be better or at least equivalent to the traditional averaging out technique, but it offered better spatial resolution than the traditional method. This technique could also be used to perform the dosage quality assurance of treatment planning for the advanced radiation treatment technology, for example, the intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT).

Fig. 5. The percentage differences between the normalized delivered dose with the original, averaged and filtered data for the second film

Fig. 6. The percentage differences between the normalized delivered dose with the original, averaged and filtered data for the third film.

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REFERENCES

Liyun Chang received the M.S. degree from the Department of radiological physics, Wayne State University, USA, in 1995, and the Ph.D. degree in biomedical engineering from the National Cheng-Kung University, Tainan, Taiwan, in 2009. He is currently an assistant professor in the Department of Medical Imaging and Radiological Sciences, I-Shou University, Kaohsiung, Taiwan. He was a clinical medical physicist in hospital for 15 years. His major research interests include evolutionary optimization and innovative techniques applied to the field of radiation therapy. He published more than 10 refereed journal papers and 15 conference papers as first author.