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Evaluation of Scanner Response with Radiochromic EBT3 Film in Radiation Therapy

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ABSTRACT

The study quantified the performance and evaluated a flatbed scanner, Epson Stylus CX5900 used for scanning the radiochromic EBT3 films for dosimetry with two other widely used commercial scanners. The performance of each scanner was based on constancy and uniformity. Scanners were tested using film irradiated with doses ranging from 0-500 cGy using 1.25 MeV cobalt-60 isotope. Image J software was used for analysing the scanners. The average dose discrepancy (δ) in percentage of the delivered dose was 0.65 % and standard deviation (σ) of 0.92 for the Epson Stylus CX5900 Scanner.

Keywords: Scanner; Cobalt-60; EBT3 film; Dosimetry; Calibration

I. INTRODUCTION

The radiochromic film widely used is targeted to measure the absorbed doses of ionizing radiation for high energy photons, electron and proton beams [1, 2]. Additionally, the radiochromic film shows low linear energy transfer (LET) and energy dependence over a wide range of beam energies used in radiation therapy [3, 4, 5]. EBT3 film is a new type of radiochromic film which serves as radiation detector in radiation therapy with greater uniformity of less than 1% [6] and within 1.5% according to Reinhardt et al., [7]. This film provides significant performance in the dose range up to 10 Gy, and it is a nearly tissue equivalent that develops blue when irradiated with absorption maxima at approximately 633nm. The EBT3 optical density changes stabilizes rapidly within 2 hours of waiting time window [6]. The film consists of H (56%), C (27.6%), O (13.3%), Al (1.6%) and Li (0.6%) with effective atomic number of 7.26 [8]. EBT3 films are comparatively hardy with the active layer protected on both sides by clear polyester film substrates. The active layer incorporates a yellow dye, decrease ultraviolet and light sensitivity that enables multi-channel dosimetry. This allows the film to be immersed in water for short periods and handled by the edges according to the recommendation of the manufacturer's specification. The recommended protocol procedure for radiometric film dosimetry described by the AAPM TG-55 Report 63 [5, 9] was used for the study. The radiochromic EBT3 film is symmetrical, therefore it can be scanned with either side facing the light source on the flatbed colour scanner. The symmetric layer configuration of the EBT3 film allows the elimination side orientation dependence, and the presence of microscopic silica particles embedded into the polyester substrate preventing the formation of Newton's rings in images obtained using a flatbed scanner [10]. This study was conducted to investigate and evaluate scanners appropriate for EBT3 dosimetry. This is important because the number of photons reaching the EBT3 film is a function of the intensity of the radiation and the time that the film is exposed to the radiation. Therefore, the type of scanner to be used in scanning the film for dosimetry is essential.

II. METHODS AND MATERIAL

Design and Calibration

The radiochromic EBT3 film dosimeter with product code 828206, from Ashland Speciality Ingredients was used in the study. The EBT3 film has 10 films per box and dimensions of 12.8 x 14.7''. The sheet (12.8 x 14.7'') of the EBT3 film was cut into rectangular pieces of dimensions 2 cm x 3 cm for easy orientation by using a sharp scissor.

A water phantoms made of PMMA was used for the film calibration irradiation for Cobalt-60 source. The field size (FS) used for the irradiation of the films was 10 cm x 10 cm at the isocenter and the source to surface distance (SSD) was set at 100 cm for cobalt-60 treatment machine.

The EBT3 films were placed perpendicular to the beam central axis at a depth of 5 cm in the water phantom. Correction and scaling factors was corrected for in the PPMMA water phantom. One of the pieces of the film was placed in the water phantom and were exposed at dose range of 0 - 500 cGy for dose levels of 0, 20, 40, 80, 160, 240, 320, 400, 500 cGy as shown in Figure 1. The dose values were calculated and converted to treatment time (TT) according to the relation as:

$$TT = \frac{Prescribed\,Dose}{Percentage\,Depth\,Dose * Dose\,Rate * Scatter\,factor} \quad (1)$$

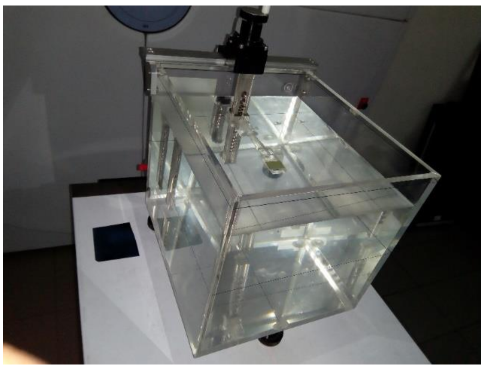

Figure 1: EBT3 film irradiation setup

Digitization

Three different scanners (Epson Stylus CX5900, Scanner A and Scanner B) were used to evaluate an appropriate scanner in scanning the EBT3 films. The EBT3 films were stored in a dark location until it was scanned. All the films were scanned in the landscape orientation in order to reduce variations within the film as recommended by the manufacturer and Menegotti et al., [11]. The films were positioned in the centre of the scanner in the direction perpendicular to the scan direction. Uniformity test at a reproducible central location on the scan surface was checked. This was checked by placing the unexposed films on the scanner and scanned. To keep track of orientation, the exposed films were labelled A, B, C, D, E, F, G, and H at the bottom left corner which corresponded to the doses of 20, 40, 80, 160, 240, 320, 400, 500 cGy respectively for the photon of energy 1.25 MeV. The EBT3 film scanned image saved in tagged image file format (TIFF) was split into red, green and blue (RGB) component using image processing software, Image J 1.46r (64 bit) (National Institute of Health, Bethesda, MD). A region of interest (ROI) of 0.4 cm x 0.6 cm was chosen for each scanned image and colour channel.

The relationship between the dose to the film and the response when the film is exposed was determined as the sensitometric curve for the beam energy. The curve provides information for the film response conversion. The optical densities defined as the $\log_{10} I_0/I$, where is I_0 the light intensity measured in the absence of the film and I is the intensity transmitted through the film in a direction perpendicular to its plane of the film response were determined for the scanners using the mean pixel values from the image data. The optical density of the film scanner response was calculated using the equation:

$$OD = -log_{10}\left(\frac{Mean\ Pixel\ Value_{exposed}}{Mean\ Pixel\ Value_{\ unexposed}}\right) \quad (2)$$

III. RESULTS AND DISCUSSION

Sensitometric Curve

A film sensitometric curve or H-D curve (named after developers Hurter and Driffield) was determined to know the relationship between the applied exposure and the resulting film density. Figure 2 shows the three RGB film characteristics curves with the exposures for the beam energy of 1.2 MeV.

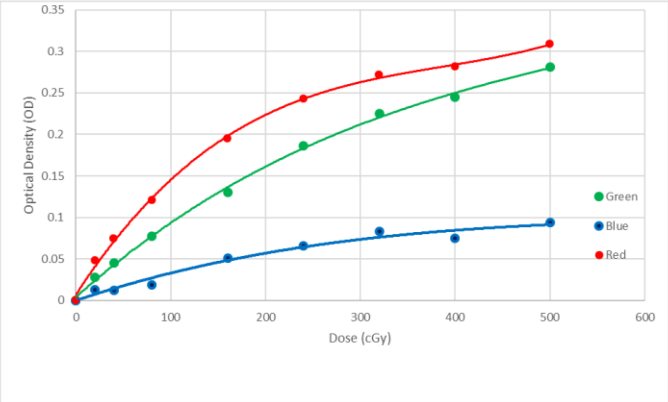

Figure 2: Characteristic Curve for 1.25 MeV Beam Energy

It was observed in Figure 2, that the density of the film increased with increasing exposure. The response curves of the EBT3 film optical densities scanned in the red and green channels were above the curve for the blue channel. This results were in agreement with the response curve of EBT film [12]. The red channel showed a relatively high slope because the signal is highly dose dependent than the blue which has a relatively low slope because the signal has weak dose-dependent. Consequently, the red channel exhibited the highest response, therefore the red channel was used for the image analysis of the fit.

The red channel pixel values obtained from the calibration curve were converted into optical density using the 3rd order polynomial. The estimated regression equation obtained between the response variable (dose) and the predicator (OD) was used to calculate the absorbed dose delivered and measured from the optical densities of the film.

EBT3 Scanners

Figure 3 shows a plot of the three different scanners studied, and with the scanned images analysed using Image J.

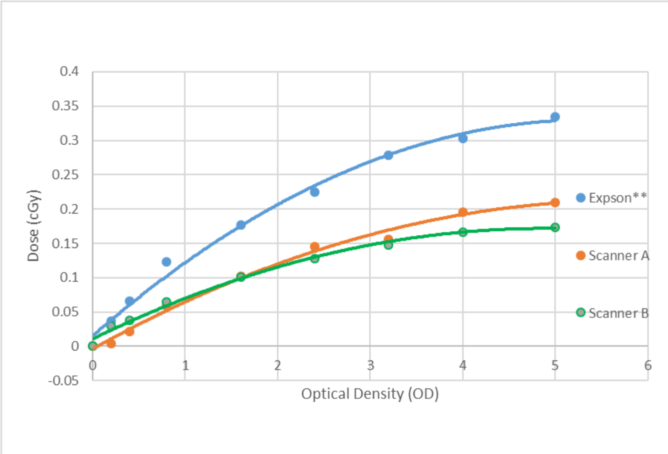

Figure 3: Scanner Response

The graph in Figure 3 shows the optical densities of the three scanners (Epson Scanner, Scanner A and Scanner B) versus the dose delivered. It was observed that all the three scanners had a perfect correlation fit (R^2 >0.99). The Epson Stylus CX5900 showed the greatest response in the spectrum, while Scanner B showed a relative low response. The percentage error (δ) was estimated for the measured dose and the expected doses for Epson Stylus CX5900 Scanner. Table 1 shows the results of the measured doses based on equation (2).

Table 1: Epson Scanner Response to Doses

Expected Dose (cGy)	Measured Dose (cGy)	%Error ($\lvert\delta\rvert$)	Standard deviation (σ)
0	0	0	0
20	19.97499	0. 12521	0.017685
40	39.11834	2.25383	0.623428
80	77.59042	3.10551	1.703830
140	144.8076	3.31999	3.399487

160	157.4514	1.61866	1.802132
320	321.2030	0.37453	0.850649
400	395.7213	1.081241	3.025498
500	496.6558	0.673344	2.364706

The discrepancy δ between the measured dose $D_{measured}$ and the expected dose $D_{expected}$ was calculated according to the relation:

$$|\delta|\ \% = \frac{D_{expected} - D_{measured}}{D_{measured}} \times 100 \qquad (4)$$

δ was calculated for each measurement to estimate the difference between the actually measured, and the calculated dose at the central beam. The average dose discrepancy (δ_{avg}) calculated was 0.645409 % and its standard deviation (σ) of 0.924529. The percentage error calculated was between 0. 13 % and 3.32 %. The standard deviation also ranged from 0.02 to 3.40. These values might be as a result of lack of uniformity in the scan area, the scanner stability and the response of the film on orientation dependence [12, 13, 14, 15, 16].

Currently, the manufacturers of EBT3 film recommends that a 48-bit (16-bit per channel) flatbed RGB scanner, with FilmQA software should be used for scanning. This is because of the scanner's ability to produce data response in three colour channels, red, green and blue. Epson scanners are particularly recommended due to their large scanning area. The scanning parameters of the flatbed RGB scanner is of resolution of 75 dpi, no colour corrections with a professional scan mode and transparency document type. With the Epson Stylus CX5900 Scanner used in the study, the image type is of 24-bit colour, resolution of 75 dpi, no colour corrections, professional scan mode and a reflective document type.

Farah et al., performed an experiments with the Varian TrueBeam 1.6 accelerator by was flatbed EPSON 10000 XL and HP Scanjet 4850 in reflection mode to compare the EBT3 film responses of doses up to 500 cGy for both photons and electrons [17]. They concluded that, the reflective scanning method could be used on EBT3 as an economic alternative to the transmission method. In addition, the behavior for doses ranging from 0 to 40 Gy corroborated the results reported by Borca et al. [6] for EBT3 film.

From the results, it was observed that the Epson Stylus scanner used for the study was appropriate in scanning EBT3 films for dosimetry.

IV. CONCLUSION

The study found the Epson Stylus CX5900 scanner to be an appropriate alternative for film dosimetry with the film providing a reliable relative dose measurement. Different scanners used might not be sensitive to the EBT3 films in the scanning of the measured doses. Therefore, the type of scanners to be used in reading or scanning the EBT3 films is very important.

Additionally, care should be taken to place the EBT3 film at the center of the scanner bed for reproducibility and also its orientation should be consistent because the light from the lamp is not emitted evenly.

The average percentage error for the study measurement was within 1% uniformity as reported by Borca et al., (2013).

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