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Microarticle

Auto-development issue in quality assurance of biological X-ray irradiator using Gafchromic EBT3 film

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ABSTRACT

Radiochromic films are convenient dosimeters for quality assurance of biological X-ray irradiators. However, their calibration curves (optical density vs. radiation dose) can have relatively short lifespans due to non-catalytic auto-development. In the present work, "corrected" calibration curves were proposed, which were constructed based on the darkness of the unexposed film before non-catalytic development. The "corrected" calibration curves enabled the use of a previous calibration curve which had expired due to non-catalytic development.

Introduction

Radiochromic films change colors upon exposures to radiation doses and are convenient dosimeters for quality assurance of biological X-ray irradiators [3]. Radiochromic film dosimetry methods rely on calibration curves to convert measured optical densities of irradiated films to irradiation doses. Girard et al. [5] reported the non-catalytic development (or referred to as "auto-development") for the Gafchromic EBT2 film in the absence of catalysts such as energetic photons. In the present work, "corrected" calibration curves were proposed. Since the EBT2 film was replaced by the new EBT3 film, our first task was to confirm the auto-development in the EBT3 film. The second task was then to establish the "corrected" calibration curves for the EBT3 film.

Materials and methods

The non-catalytic development of Gafchromic EBT3® film was studied through temporal changes in the X-ray calibration curves. All EBT3 films belonged to the same batch (Lot No. A03181301). X-ray irradiation was performed on $1 \times 2.5\ cm^2$ EBT3 films using the X-RAD 320 Irradiator (Precision X-ray (PXi), Inc. North Branford, Connecticut). The voltage and current were set as 320 kVp and 12.5 mA, respectively, using a filter with thickness of 2.5 mm, made of (1.5 mm Al+ 0.25 mm Cu+ 0.75 mm Sn, and the source-to-surface distance was 50 cm. A dosemeter (UNIDOS® E Universal Dosemeter, PTW, Freiburg, Germany) was used to monitor the dose. The films were put under a uniform $10 \times 10\ cm^2$ field. A total of 17 different doses between 0 and 1500 cGy were used, and the experiments were repeated with three different films. Subsequent to X-ray irradiation, all exposed EBT3 films were transferred into light tight containers and stored in an air-conditioned laboratory so the relative humidity and temperature were kept constant at ~65% and ~24 °C, respectively. After 24 h, the coloration changes in the films were quantified using the protocol described by Chun and Yu [4]. For each studied dose value, three films were employed. The entire film area (i.e., $1 \times 2.5\ cm^2$) of each exposed film was scanned for three times using an Epson Perfection V700 desktop flatbed scanner with a resolution of 50 dots per inch (dpi). The responses of radiochromic films were different for different scanning directions [2]; [6] and therefore the same scanning direction perpendicular to the long edge of the original rectangular EBT3 film (landscape direction) was employed in the present experiments. The reflectance mode was chosen to capture 48 bit RGB color images. The raw pixel value (P_t) from each scan of a film was obtained by analyzing the central part of the film with an area of $0.5 \times 1.5\ cm^2$ without application of filters or correction functions. The red component of the images was analyzed using the ImageJ software (http://imagej.nih.gov/ij/). The mean pixel value ($\bar{P}_t$) obtained from the three scans was used to calculate the net reflective optical density (*Net ROD*') of that particular sample. The coloration of the scanned area in

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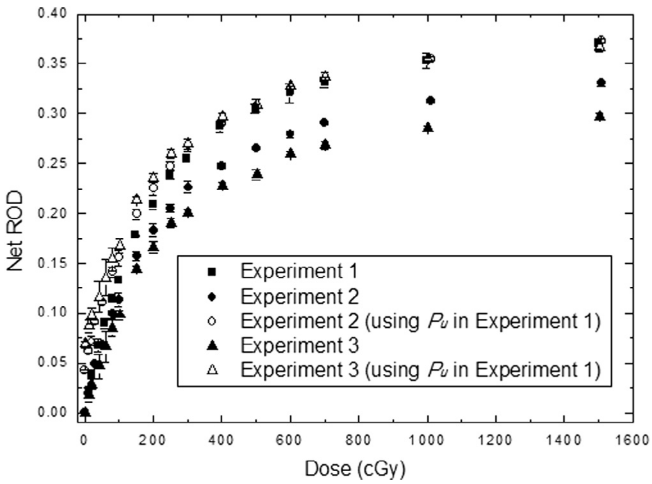

Fig. 1. Calibration curves of *Net ROD* against the X-ray dose (cGy) for EBT3 films. Solid squares: data from Experiment 1 obtained in May 2015; solid circles: data from Experiment 2 obtained in November 2015; solid triangles: data from Experiment 3 obtained in May 2016; open circles: data from Experiment 2 with *Net ROD* values computed using the P_u values obtained in Experiment 1 ("corrected" calibration curve); open triangles: data from Experiment 3 with *Net ROD* values computed using the P_u values obtained in Experiment 1 ("corrected" calibration curve). The error bars represent the standard deviations of the *Net ROD'* values obtained through the three films for each studied X-ray dose.

each irradiated film was quantified through *Net ROD*' as *Net ROD*' = $\log(\bar{P}_u/\bar{P}_t)$, where $\bar{P}_u$ and $\bar{P}_t$ were the mean pixel values recorded for the three scanning of the unexposed and the exposed films, respectively. The average net reflective optical density (*Net ROD*) for each studied dose in the range from 0 to 1500 cGy was found by averaging the *Net ROD*' values obtained from the three samples. The pixel values of 0 and 255 were taken to be complete black and complete white, respectively. Our earlier studies showed that the V700 scanner when in reflectance mode produced <2% variation in the coloration of a non-irradiated EBT film (predecessor of the EBT2 film) when scanned 100 times [1]. Since the EBT, EBT2 and EBT3 films have the same active radiochromic compound, the coloration of a non-irradiated EBT3 film upon three scans should be negligible.

Results and discussion

Fig. 1 shows the calibration curves of *Net ROD* against the X-ray dose (cGy) for EBT3 films obtained in May and Nov 2015 and in May 2016, which confirmed the presence of non-catalytic auto-development of EBT3 films. Fig. 1 also shows the calibration curves of *Net ROD* against the X-ray dose obtained in Nov 2015 and May 2016, but with *Net ROD* values computed using the $\bar{P}_u$ values obtained in May 2015. These calibration curves overlap with the calibration curve obtained in May 2015 for X-ray doses larger than 500 cGy, and are the "corrected" calibration curves which can help avoid frequent time-consuming construction of new calibration curves and can remove a significant obstacle to radiochromic film dosimetry in the quality assurance of biological X-ray irradiators.

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