To determine optimum calibration method of EBT3 film

Poster No.: R-0229  
Congress: 2014 CSM  
Type: Scientific Exhibit  
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Keywords: Oncology, CT, Dosimetry, Cancer  
DOI: 10.1594/ranzcr2014/R-0229

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Aim

The purpose of this work is to determine the optimum channel (red, green, blue, or a combination thereof) for calibration of EBT3 film for dose verification of radiotherapy plans. We also examined the accuracy of using a single calibration curve for a batch of film, in comparison to performing a calibration for each sheet or a small region of film.

Methods and materials

Ten sets of calibration squares, from a single batch of EBT3 film (lot number 7151301), were irradiated during patient specific QA of hypofractionated VMAT and stereotactic plans (maximum dose between 10 and 20 Gy per fraction). Each calibration typically used 10, 3 cm x 3 cm, squares which were aligned along the central longitudinal axis of a EPSON EXPRESSION 10000 XL scanner (see Figure 1). The scanner was operated with SilverFast (LaserSoft Imaging) software, in transparency mode, at 72 dpi, with colour correction disabled. To reduce noise due to random fluctuations of the light signal, 16 scans were averaged and saved as a single 48 bit uncompressed TIF image. The central 1 cm x 1 cm region of each square was averaged to obtain the response (pixel value) corresponding to the delivered dose (cGy).
Fig. 1: Raw 48-bit TIF image of a set of EBT3 calibration squares irradiated from 0 to 19.4 Gy

References: Princess Alexandra Hospital - WOOLLOONGABBA/AU

Five forms of raw response data were compared: the individual red (R), green (G) and blue (B) channels; the average of the red and green channels, Av(R,G); and the average of the red, green and blue channels, Av(R,G,B). The sensitivity was defined as the absolute change in pixel value per change in dose. (The absolute value was taken because the pixel value decreases with increasing dose.) Using the assumption that the signal-to-noise ratio (SNR) of calibration data is proportional to the square root of the number of combined channels, the measured sensitivity of the R+G channel was scaled by sqrt(2) and the R+G+B channel by sqrt(3).

Results
Figure 2 shows the response versus dose for the individual red, green and blue channels. The standard error of the mean response has not been displayed on the following plots as it is too small to be visible. For example for the data set corresponding to Figures 2-4 below, the standard error of the mean varied from 0.007% to 0.02% of the mean for 0 to 19.4 Gy respectively, while the standard deviation varied from 0.2% to 0.8% of the mean.

![Graph showing pixel value versus cGy for red (R), green (G), and blue (B) channels.]

**Fig. 2:** Response (pixel value) versus dose for the individual red (R), green (G) and blue (B) channels of EBT3 film calibration squares.

**References:** Princess Alexandra Hospital - WOOLLOONGABBA/AU

Figure 3 shows the change in response per change in absorbed dose given to the calibration squares. This is referred to as a sensitivity plot since the higher the change in response, the easier it is to distinguish the dose from similar dose delivered to neighbouring regions. For single channel data, the red channel was most sensitive for absorbed dose below 4-5 Gy, while the green channel was optimum for irradiation above this value. Combining channels increases sensitivity over all dose ranges with the combined red and green, Av(R,G), channel being most sensitive in the lower dose range (below 4-5 Gy), and combined red, green and blue channel, Av(R,G,B) for higher doses.
**Fig. 3:** Sensitivity plot: negative change in response per change in absorbed dose of EBT3 calibration squares. The negative of the response change is taken as the response (pixel value) decreased with applied dose. Since the combined channels \( \text{Av}(R,G) \) and \( \text{Av}(R,G,B) \) consist of two and three times the amount of data, their sensitivity values have been scaled by the square root of two and three respectively.

**References:** Princess Alexandra Hospital - WOOLLOONGABBA/AU

A noticeable discontinuity is observable in Figure 3. One to several discontinuities were observable in sensitivity plots of all 10 data sets and were visibly observable in half of the response versus dose plots.

Figure 4 below overlays the red channel response versus dose plots for all 10 data sets. Variance in the response is visibly noticeable. As a quantification of this variance, for a delivered dose of 500 cGy the red channel pixel value varied from a minimum of 96.8% to a maximum of 103.5% (i.e. a range of 6.7%) of the mean response of the 10 data sets.
**Fig. 4**: Response vs absorbed dose plots for the red channel for 10 calibration data sets from the same lot of EBT3 film.

**References**: Princess Alexandra Hospital - WOOLLOONGABBA/AU

Figure 5 overlays the red channel response that has been normalized to the 0 cGy (unirradiated) calibration squared. The normalized response varies from 98.5% to 101.6% (a range of 3.1%) of the mean of the 10 data sets.
Fig. 5: Normalised response vs absorbed dose plots for the red channel for 10 calibration data sets from the same lot of EBT3 film. For each data set, the response has been normalised to the response of the 0 cGy (non-radiated) square.

References: Princess Alexandra Hospital - WOOLLOONGABBA/AU

Conclusion

When using data from a single channel, the red channel is most sensitive below 4-5 Gy, while the green channel is more sensitive for higher doses. Combining data from R, G and B channels increases the sensitivity of the EBT3 dose versus pixel value calibration curves. It is recommended to use the combined R+G channel for typical IMRT/VMAT treatments of approximately 2 Gy per fraction, and to use the combined R+G+B channel for hypofractionated and stereotactic treatments.

Significant variation in response to delivered dose was observed for EBT3 film from different sheets from the one lot. It is likely that applying a calibration curve to a sheet of film that is not close to the calibration films in the batch will result in increased error in dose.
estimation. However the response variation was reduced by normalising the response to the pixel value of the non-radiated calibration square.

**Personal information**

**References**

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