TECHNICAL NOTE

# Scanning orientation effects on Gafchromic EBT film dosimetry

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## Abstract

Gafchromic EBT film, a new high sensitivity radiochromic film has been tested for variations in optical properties due to scanning orientation. Gafchromic EBT film has been shown to produce a scanning orientation effect whereby variations in measured relative optical density are found due to the films orientation relative to the scanner direction. This relative optical density change was found to be relatively consistent for different films exposed to varying dose levels ranging from 0 Gy to 3 Gy. A maximum variation of 0.0157 ± 0.0035 in optical density (OD) was found. This relates to an approximate 15 % variation in net OD for a 50 cGy irradiated film and 4 % variation for a 3 Gy irradiated film. No noticeable effects or variations were seen with changing scanning resolution or with the film placed “up or down” during scanning. Other Gafchromic film types were tested and compared to EBT for unirradiated film to assess the magnitude of this orientation effect on the scanner used and results showed that EBT produced a significantly higher effect that MD-55-2, HS, XR type T and XR type R film by up to 3 times. As such, providing the same orientation of EBT film when scanning for dosimetric analysis becomes an essential part of EBT film dosimetry.

**Key words** Gafchromic EBT, radiochromic film, densitometry, orientation

## Introduction

Gafchromic film products for diagnostic radiology [1,2,3,4] and radiotherapy applications [5,6,7,8,9,10,11] have expanded other the last few years with films specifically designed for niche areas becoming commercially available. Some of these films include the Gafchromic film range such as MD-55-2 and HS. These films were designed to match the characteristics of high energy radiotherapy x-ray beams with low energy dependence and relatively low absorbed dose requirements for analysis. Film types XR type T and XR type R were produced for diagnostic purposes producing a relatively energy independent response in the diagnostic x-ray energy range. Recently EBT has been released which provides a higher level of dose sensitivity [12,13,14] and lower energy response [15] variations and seems to be ideally suited for fractionated radiotherapy applications. Gafchromic EBT films are produced with various layers in their construction as well as a needle like active radiochromic material layer. These types of constructions can produce variations in scattering effects of light with varying rotational reference during scanning. Various scanners can also produce variations in light collection properties due to effects such as polarization [16,17,18,19]. As such the orientation of EBT film compared to the orientation of a scanning light source can produce a variation in measured optical density. The manufacturer has highlighted this [20] and they recommend the same film orientation is used for all film analysis. In this note we further investigate the effects of film orientation relative to the scanning device to measure the variations that occur and compare these results to previous types of Gafchromic film products for analysis.

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## Materials and methods

Experiments were performed with radiochromic film type Gafchromic EBT (ISP Corp, Wayne NJ, USA) to analyse the effects of film/scanner orientation during readout. EBT films is constructed with a multi-layer approach consisting of the active polymer along with polyester protective coatings which allows the film to be easily handled and minimizes effects from ultraviolet exposure [21,22]. The effective atomic number of the EBT film is $Z_{eff}$ = 6.98 compared to water $Z_{eff}$ = 7.42, a comparatively good match. Batch no. 34267-004 was used for this experiment. The results for film orientation of EBT Gafchromic were also compared to other Gafchromic film products. These being, Gafchromic MD-55-2 (Batch No.#H1146MD55), Gafchromic HS (Batch No. I0144HS), Gafchromic XR type R (Batch No. J0123XRR) and Gafchromic XR type T (Batch No. k02b28XRT). These film types were tested for orientation effects using the same scanner and set up parameters as EBT to compare the magnitude of the orientation effects. For dose delivery, the films were positioned in a solid water [23] phantom of dimensions 30 cm x 30 cm x 30 cm. Measurements to assess the effects of film orientation relative to the scanner orientation have been made using a standard desktop scanner. Gafchromic films have been analysed using a PC desktop scanner and Image J software. The scanner is a Hewlett Packard ScanJet with scanning resolution of up to 1200 pixels per inch. The images produced were 16 bit RGB colour images. These images were analysed with the full RGB image. Early versions of Gafchromic film required the image to be split into the three colour components and analysis performed in the red region only to enhance the colour change [24,25]. Pieces of 4 cm x 4 cm square film were irradiated using a 6MV linear accelerator produced x-ray beam to the given dose levels ranging from 0 Gy up to 3 Gy. The film was left for 24 hours before analysis to minimize effects from post irradiation colouration [26] although a shorter time period could have been used for Gafchromic EBT [27]. The films were placed on the flat bed scanner with 0 degrees angle quoted with the EBT films coating direction being parallel to the length of the scanner plate. Scans were performed with various angular intervals. Maximum and minimum transmission value angles were also measured and compared for the various film types. Tests were also performed using different scanning resolutions ranging from 75 pixels per inch to 1200 pixels per inch. Tests were also performed for up and down film orientations to evaluate any effects caused by scanning face up or face down. Results for EBT orientation effects are compared to results found for other radiochromic film types studied earlier [16,22]. Results shown are for unirradiated films.

## Results and discussion

Figure 1 shows the effects of film orientation within the scanner for Gafchromic EBT film at dose levels of 0 Gy, 50 cGy, 100 cGy and 300 cGy. Results show that a measurable orientation effect is seen at all dose levels measured. Results are quoted as net optical density with the maximum transmission value for our unirradiated film being our reference light intensity level. As can be seen in figure 1, a variation in net OD from 0 ± 0.003 to 0.0157 ± 0.0035 over a 90 degree change in orientation for the unirradiated film occurs in a reproducible pattern. For our scanner, the maximum/minimum net OD values or transmission occurred with the film positioned at –20 degrees / 70 degrees orientation to the scanner. The same orientation angle was found for all irradiated EBT films for

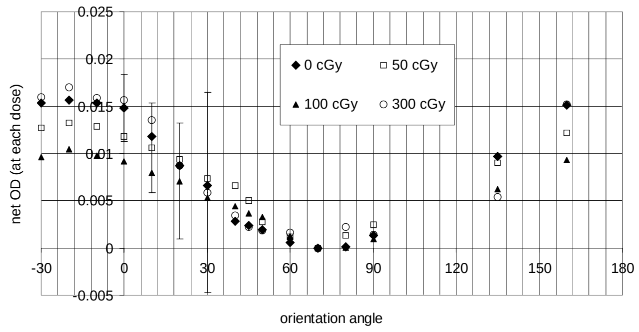


**Figure 1.** *Variations in net optical density as a function of scanning orientation for Gafchromic EBT for various irradiated dose levels. The reference light intensity for each curve is taken as the maximum transmission at the specified dose level.*

max/min positions. Figure 1 also shows similar results at dose levels of 50 cGy, 100 cGy and 300 cGy respectively. The errors quoted are the measured variations (1SD of mean) for each film piece based on 10 readings. Of interest is the magnitude of the change in net OD for orientation at all dose levels. This is similar for all dose levels tested and the average found to be 0.014 ± 0.002. This relates to an approximate dose equivalency in the order of 10cGy variation. As such the percentage magnitude of the associated errors are dependant of the size of the measurement made. A smaller dose would produce a significantly larger error than higher doses. That is, the change in net OD from film orientation is relatively independent of absorbed dose or film darkness with the limits of uncertainty for this analysis. No significant variations in results were seen with changes in scanning resolution from 75 dpi up to 1200 dpi. No significant variations in measured OD were found for films scanned up or down through all orientation angle measured. Thus the scanning resolution and the films placed either face up or face down produced no significant effect on results. The manufacturers of EBT through their web site [20] have given warnings concerning the effects of film orientation quoting results for film analysis in perpendicular directions. A larger variation for different scanner types is seen. Our results show a variation nearly an order of magnitude lower than the quoted Vidar VXR-16 densitometer. Our results do show the nature of the variation with varying orientation angle. It is expected that the cause of this variation be due to the scattering properties of light through the EBT film causing a variation in transmitted intensity. The shape and orientation of EBT films active layer as shown by Rink et al [14] 2005 gives rise to the effects with the films active particles having a needle like form with size in the order of 1-2 µm diameter and 15-25 µm in length. The long axis of the particles in general aligns with the coating direction of the film during production. Older style films produced a more random particle orientation without the needle like form [14]. Due to the particle alignment, it was perceived that the orientation effects seen with EBT would be more pronounced than its predecessors. Figure 2 shows results for a comparison of variations in measured net OD for

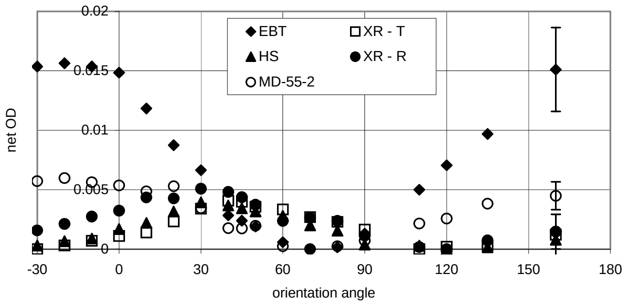


**Figure 2.** *Variations in net optical density as a function of scanning orientation for various Gafchromic film types.*

various types of Gafchromic films. Results show the net OD variations for each film type as a function of film orientation. All film types exhibit some form of variation with angle. The EBT film produced the highest variation, which was nearly three times larger than most other films. The MD-55-2, HS, XR type R and XR type T film all produce albeit to a lesser extent, a variation with film orientation with maximum changes in the region of approximately 0.004 to 0.006 as compared to 0.0157 ± 0.0035 for EBT. As such the orientation effect has been significantly increased for the relatively new film Gafchromic EBT. This film type is becoming extensively used in radiotherapy applications. To increase the level of accuracy in results obtained through EBT film dosimetry it does become significantly important to scan films with the same orientation each time. This includes experimental and calibration films. It is also important to mark smaller EBT films which have been cut to size with the coating direction orientations so that confusion or inaccuracies do not appear when analysis is performed after measurement are performed.

## Conclusion

Variations in measured optical density of Gafchromic EBT, radiochromic film are seen as a function of film versus scanner orientation. This variation is significant and measurable with fluctuations up to three times larger than seen with older types of Gafchromic film products, thus becoming a more significant effect. No significant variations in orientation effects were seen due to scanning resolution or whether the films were scanned face up or face down. Inaccuracies in measured optical density and thus measured dose from orientation effects can be minimized by routinely scanning films with the same orientation every time.

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## References

1. Butson, M.J., Cheung, T. and Yu, K.N. *Visible absorption properties of radiation exposed XR type T radiochromic film*, Physics in Medicine and Biology, 49, N347-351, 2004.
2. Butson, M.J., Cheung, T. and Yu, K.N. *XR type R radiochromic film x-ray energy response*, Physics in Medicine and Biology, 50, N195-N199, 2005.
3. Cheung, T., Butson, M.J. and Yu, K.N. *Reflection spectrometry analysis of irradiated GAFCHROMIC XR type R radiochromic films*, Applied Radiation and Isotopes, 63, 127-129, 2005.
4. Dini, S.A., Koona, R.A., Ashburn, J.R. and Meigoonia, A.S. *Dosimetric evaluation of GAFCHROMIC XR type T and XR type R films*, J Appl Clin Med Phys. Winter;6(1):114-34. Epub 2005 Jan 12, 2005.
5. Butson, M.J., Yu, K.N. and Metcalfe, P.E. *Extrapolated surface dose measurements with radiochromic film*, Medical Physics, 26, 485-488, 1999.
6. Butson, M.J., Yu, K.N., Cheung, T. and Metcalfe, P. *High sensitivity radiochromic film dose comparisons*, Physics in Medicine and Biology, 47, N291-N295, 2002.
7. Butson, M.J., Cheung, T. and Yu, K.N. *Radiochromic film: the new x-ray dosimetry and imaging tool*, Australasian Physical & Engineering Sciences in Medicine, 27, 230, 2004.
8. Cheung, T., Butson, M.J. and Yu, K.N. *Multilayer Gafchromic film detectors for breast skin dose determination in vivo*, Physics in Medicine and Biology, 47, N31-37, 2002.
9. Klassen, N., Zwan, L. and Cygler, J. *Gafchromic MD-55: investigated as a precision dosimeter*, Med phys 24 1924-1934, 1997.
10. Mack, A., Mack, G., Weltz, D., Scheib, S.G., Bottcher, H.D. and Seifert, V. *High precision film dosimetry with GAFCHROMIC films for quality assurance especially when using small fields*, Med Phys. Sep;30(9):2399-409, 2003.
11. Meigooni, A., Sanders, M., Ibbott, G. and Szeglin, S. *Dosimetric characteristics of an improved radiochromic film* Med. Phys.; 23:1883-1888, 1996.
12. Cheung, T., Yu, K.N. and Butson, M.J. *Measurements of centi-Gray x-ray dose levels with radiochromic film*, IEEE Transactions on Nuclear Science, accepted for publication, 2005.
13. Butson, M.J., Cheung, T. and Yu, K.N. *Absorption spectra variations of EBT radiochromic film from radiation exposure*, Physics in Medicine and Biology, 50, N135-N140, 2005.
14. Rink, A., Vitkin, I. and Jaffray, D. *Characterization and real-time optical measurements of the ionizing radiation dose response for a new radiochromic medium.* Med Phys. Aug; 32(8):2510-6, 2005.
15. Cheung, T., Butson, M.J. and Yu, K.N. *Weak energy dependence of EBT Gafchromic film dose response in the 50 kVp - 10 MVp X-ray range*, Applied Radiation and Isotopes, 64, 60-62, 2006.
16. Butson, M.J., Yu, K.N., Cheung, T. and Inwood, D. *Polarization effects on a high sensitivity radiochromic film*, Physics in Medicine and Biology, 48, N207-211, 2003.
17. Cheung, T., Butson, M.J. and Yu, K.N. *Evaluation of a fluorescent light densitometer for radiochromic film analysis*, Radiation Measurements, 35, 13-16, 2002.
18. Chiu-Tsao, S.T., Duckworth, T., Zhang, C., Patel, N.S., Hsiung, C.Y., Wang, L., Shih, J.A. and Harrison, L.B. *Dose response characteristics of new models of GAFCHROMIC films: dependence on densitometer light source and radiation energy*, Med Phys. Sep;31(9):2501-8, 2004.

19. Gluckman, G.R. and Reinstein LE. *Comparison of three high-resolution digitizers for radiochromic film dosimetry,* Med Phys. Aug; 29(8):1839-46, 2002.
20. ISP Corp web site, www.ispcorp.com, 2005.
21. Butson, M., Yu, P. and Metcalfe, P. *Effects of readout light sources and ambient light on radiochromic film*, Phys Med Biol 43 2407-2412, 1998.
22. Butson, M.J., Yu, K.N., Cheung, T. and Metcalfe, P.E. *Radiochromic film for Medical Radiation Dosimetry*, Materials Science & Engineering R: Reports, 41, 61-120, 2003.
23. Constanitinou, C., Attix, F. and Paliwal, B. *A solid water phantom material for radiotherapy X-ray and gamma ray beam ray calculations,* Med Phys. 9 436-441, 1982.
24. Devic, S., Seuntjens, J., Sham, E., Podgorsak, E.B., Schmidtlein, C. R., Kirov, A. S. and Soares, C. G. *Precise radiochromic film dosimetry using a flat-bed document scanner,* Med Phys. Jul;32(7):2245-53, 2005.
25. Devic, S., Seuntjens, J., Hegyi, G., Podgorsak, E.B., Soares, C.G., Kirov, A.S., Ali, I., Williamson, J.F. and Elizondo, A. *Dosimetric properties of improved GafChromic films for seven different digitizers,* Med Phys. Sep; 31(9):2392-401, 2004.
26. Niroomand-Rad, A., Blackwell, C., Coursey, B., Gall, K., Galvin, J., McLaughlin, W., Meigooni, A., Nath, R., Rodgers, J. and Soares, C. *Radiochromic film dosimetry: Recommendation of AAPM radiation therapy task group 55, Med Phys* 25 (11) 2093-2115, 1998.
27. Cheung, T., Butson, M.J., Yu, K.N. *Post irradiation coloration of Gafchromic EBT radiochromic film,* Physics in Medicine and Biology, 50, N281-N285, 2005.