TECHNICAL NOTE

Does mechanical pressure on radiochromic film affect optical absorption and dosimetry?

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Abstract

EBT Gafchromic film, a new high sensitivity radiochromic film has been tested to evaluate if external pressure on the film can affect absorption spectra analysis and thus radiation dosimetry. This question arises from the fact that Gafchromic film is often cut into smaller pieces or to certain shapes for dosimetric analysis using scissors which can apply significant pressure to the sides of the film and small film pieces are placed within a solid phantom at depth which can produce significant pressure on the film if appropriate weight distribution procedures are not performed. As expected, results have shown that films cut by scissors can produce a large increase in OD near the film edge up to 5-10 mm away due to physical damage to the EBT film layers however. Films placed within a solid phantom receiving up to 39.5 kg/cm^2 pressure showed negligible differences in measured absorption spectra compared with control films subject to no external pressure. This equates to negligible external pressure effects for as much as 44 cm of 30 cm x 30 cm solid water placed on a 1 cm^2 area film piece. As such, we recommend based on results herein, that film analysis should be performed with a boundary around every film edge, which can be defined visually based in the film. Also film dosimetry in a phantom can be performed with weights up to 39.5 kg/cm^2 (or 44 cm of 30 cm x 30 cm solid water or equivalent) placed on the film without effecting the absorption spectra and thus dosimetry of radiation beams.

Key words gafchromic EBT, radiochromic film, densitometry, pressure

Introduction

There are many aspects of radiochromic films, which have made them a significant tool in radiation dosimetry over the past few years [1-5]. These include the high spatial resolution [6] the automatic development process[7] and its low energy dependent nature [8-9]. Specifically the automatic development process eliminates the use of a film processor and some associated problems. One specific problem was the size of a film piece, which could be reproducibly developed through the processor. Normally, a minimum limit on size was “big enough” to be able to successfully roll through the processor on the automated rollers. Gafchromic film being an auto developing film meant that experiments could be performed with smaller film pieces used at the specific site of interest for dosimetry in a similar fashion to how TLD’s have been used. The price of the films initially also contributed to this process as economics defined the size of film piece used. As such, small (in the order of just a centimetre square) film pieces could be used for film analysis. As with other types of film, radiochromic films produce a level of uncertainty with dose assessment. It was thought that one contributing factor to this uncertainty could be the effects of pressure place on the film during irradiation in a solid water phantom. When films are placed within a solid phantom at depth (stacked vertically so that all pressure is applied to the film), pressure is applied by the amount of material directly above it. If the film piece is small, eg 1 cm x 1 cm, and placed at a depth of 10 cm in a 30 cm x 30 cm solid water phantom, a significant pressure (approx 9 kg/cm^2) can be applied due to the fact that the entire weight is placed on the small finite thickness of the film piece. The weight is not distributed as the phantom material above the film can “balance” on the film piece directly. By applying pressure it is expected that the active layer of the film may become compressed or damaged either temporarily or permanently. This could in turn either reduce the path length for light to pass through during analysis (assuming lateral displacement of the active layer), or change the physical properties of the film sheet which could result in a change in optical density or absorption spectra properties from structural changes within the film. As such we wished to investigate if external pressure produces any effects on the dosimetric properties of the film caused by temporarily or permanently squashing of the film. This short note investigates these effects along with affects on film optical density from the pressure of cutting the film.

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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 pressure on the films due to set up procedures and film cutting. EBT film 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 [10-11]. The film construction consists of 2 active layers being approximately 17 µm thick surrounded by 2 polyester 97 µm thick protective coats and held together with a 6 µm 'surface layer' [12]. It is assumed that the active layer (or the polyester or surface layer) could be temporarily or permanently compressed by the application of pressure which would in turn effect the measured absorption spectra produced by the film. Batch no. 34267-004 film was used for this experiment. Pressure to films has been applied in two ways. Films have been placed in a solid water phantom at a depth of 5 cm for dosimetric analysis. Our standard films have been exposed at the central axis of a standard 10 cm x 10 cm 6 MV x-ray beam and doses quoted within the paper have been delivered. Our standard 0 kg/cm^2 pressure film (control film) is exposed with two film layers positions at each corner of the solid water phantom to raise the 5 cm of phantom material off the film by approximately 0.2 mm. Also, weight has been applied to the film to increase the pressure on the film by placing solid water as well as lead blocks of various weight on top of the 30 cm x 30 cm x 30 cm phantom with irradiation being performed with the gantry at 180 ° and the beam passing vertically up through the phantom. The lead blocks when positioned 25 cm behind the film do not effect the delivered dose to the film position as tested by ionisation chamber measurements. Various pressures have been applied by using different weights. The pressures were calculated by using the weight distributed over the 1 cm^2 film piece. The entire weight of the phantom was placed on the film. This was accomplished by carefully balancing the phantom on the small film piece. Results for pressure are quoted in kg/cm^2. Measurements have also been made to assess the effects of cutting the film with scissors. The films have been scanned both pre and post cutting to measure any deviations in the optical density of the film caused by the cutting. The Gafchromic film has been analysed using a PC desktop scanner and Image J software [13] as well as a Shimadzu UV-160 UV-visible recording spectrophotometer [14]. The film was left for at least 6 hours before analysis to minimize effects from post irradiation colouration [15].

Results and discussion

Figure 1 shows the absorption spectra of 5 films, which have been exposed to 2 Gy absorbed dose at 5 cm depth in a solid water phantom with various pressures applied during irradiation. The Y axis shows the calculated optical density of the film (OD = log (I_o/I_t) where I_o is the initial light intensity and I_t is the transmitted light intensity.

Pressures applied are 0, 4.5, 11.5, 24.5, and 39.5

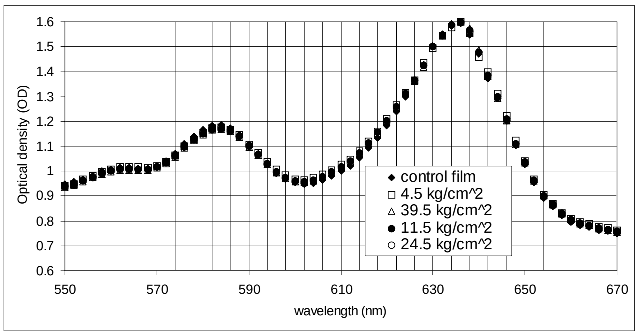

Figure 1. *Absorption spectra changes for EBT Gafchromic film when irradiated under various pressures ranging from 0 kg/cm^2 (control film) to 39.5 kg/cm^2 (0 cm to 44 cm, 30 cm x 30 cm solid water phantom material equivalent). Negligible changes are seen from pressure effects.*

kg/cm^2. The experiments were repeated 5 times and results shown are the average of the 5 data sets. Results show that a negligible difference in measured OD for all film sets is seen. Similar results are seen with other applied dose levels ranging from 0.5 Gy to 5 Gy. Small differences are noted at all wavelengths however these variations are within the measured uncertainty of analysis. When averaged over the spectra regions of 550 nm to 670 nm, which would occur with a desktop scanner at the region of analysis, using conventional EBT analysis the resultant OD values are 1.061, 1.069, 1.065, 1.062 and 1.063 for the increasing pressure values respectively. Thus less than 1 % variation is seen across the data sets with no specific trend in the values with added pressure. These results show that the effects of pressure in phantom are negligible for absolute OD analysis of EBT Gafchromic film. Thus small pieces of film can be placed and exposed within a phantom with up to 39.5 kg/cm^2 pressure on it without permanently effecting the dosimetry results. 39.5 kg/cm^2 equates to pressure applied to a 1 cm square piece of film by approximately 44 cm of 30 cm x 30 cm solid water phantom material stacked directly on top of it. This would most likely be beyond the limit of pressure applied during most normal experimental procedures for radiotherapy applications.

Experiments were also performed for pre and post film cutting to assess the effects on OD. Figure 2 shows the measured pixel density units, which are the raw light transmission values from the scanner, across a film piece, pre and post cutting. On this scale, 255 is complete transmission and 0 is no transmission of light. The distance units are an arbitrary position on an uniformly irradiated film piece which was cut at approximately the 35 mm position. Results show a marked decrease in pixel density, which is associated with an increase in opacity (cloudiness) of the film at the edge, up to 8 mm from the cut. This was the worst-case scenario recorded with most scissor cuts causing physical damage less than 1 mm. This is expected to be due to physical damage, which occurs from either a separating of the films layers or a displacement of the film layers, which is caused by the pressure and stress of the cutting process. The higher pixel density values seen at the cut position would be due to transmitted light through the small gap created by the cut edge. From our results,

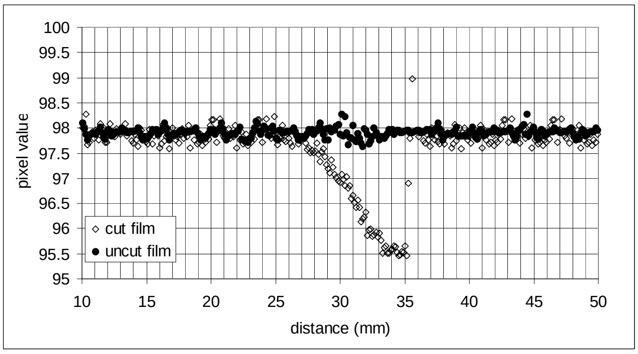

Figure 2. *Change in pixel density for an irradiated film when cut and damaged by pressure and stress. Scissors performed the cut and visible damage was seen on the film at the cut sight.*

measurable damage can occur up to 8 mm from the film edge. We would recommend that a border around the edge of the film for dosimetric analysis be used to avoid errors in dosimetry caused by such effects which can be qualitatively defined by the level of visible damage occurring. In most cases this will be 1 mm to 2 mm in size.

Conclusion

EBT Gafchromic film has been tested for dosimetric variations, which may be caused by pressure packed on the film during irradiation. Results have shown that pressures up to 39.5 kg/cm^2 do not affect measured OD when the film is read out 6 hours after irradiation. Thus no permanent effects of pressure are seen on EBT Gafchromic film. Cutting the film can however produce physical damage of the edge due to the stress and pressure applied to the film during this process which seem to be caused by the films layers separating and effects can be seen up to 8 mm from the edge from our experiments. These results show that most normal phantom pressures associated with using small film pieces in a solid phantom where relatively large pressures can be applied do not affect the optical density characteristics of the film and thus do not affect film dosimetry. Cutting does however affect the film at the edges and is related to the care taken during this process.

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References

1. Butson, M.J., Yu, K.N., Cheung, T., Metcalfe, P.E., "Radiochromic film for Medical Radiation Dosimetry", Materials Science & Engineering R: Reports, 41, 61-120, 2003.
2. Butson, M.J., Cheung, T., Yu, K.N., "Radiochromic film: the new x-ray dosimetry and imaging tool", Australasian Physical & Engineering Sciences in Medicine, 27, 230, 2004.
3. Cheung, T., Butson, M.J., Yu, K.N., "Multilayer Gafchromic film detectors for breast skin dose determination *in vivo*", Physics in Medicine and Biology, 47, N31-37, 2002.
4. Chiu-Tsao ST, Duckworth T, Zhang C, Patel NS, Hsiung CY, Wang L, Shih JA, Harrison LB.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.
5. Mack A, Mack G, Weltz D, Scheib SG, Bottcher HD, Seifert V. High precision film dosimetry with GAFCHROMIC films for quality assurance especially when using small fields. Med Phys. 30(9):2399-409, 2003.
6. Butson, M.J., Cheung, T., Yu, K.N., "Spatial resolution of a stacked radiochromic film dosimeter", 2001, Radiotherapy and Oncology, 61, 211-213, 2001.
7. Klassen N., Zwan L., Cygler J., Gafchromic MD-55: investigated as a precision dosimeter. *Med phys* 24 1924-1934, 1997.
8. Butson, M.J., Cheung, T., Yu, K.N., "XR type R radiochromic film x-ray energy response", Physics in Medicine and Biology, 50, N195-N199, 2005.
9. Cheung, T., Butson, M.J., 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.
10. Butson M, Yu P, Metcalfe P, Effects of readout light sources and ambient light on radiochromic film Phys Med Biol 43 2407-2412, 1998.
11. Niroomand-Rad A, Blackwell C, Coursey B, Gall K, Galvin J, McLaughlin W, Meigooni A, Nath R, Rodgers J, Soares C Radiochromic film dosimetry : Recommendation of AAPM radiation therapy task group 55. *Med Phys* 25 (11) 2093-2115, 1998.
12. ISP Corp web site, www.ispcorp.com, (2005).
13. Butson, M.J., Cheung, T., Yu, K.N., "Absorption spectra variations of EBT radiochromic film from radiation exposure", Physics in Medicine and Biology, 50, N135-N140, 2005.
14. Butson, M.J., Yu, K.N., Cheung, T., Metcalfe, P., “High sensitivity radiochromic film dose comparisons”, Physics in Medicine and Biology, 47, N291-N295, 2002.
15. 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.