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TECHNICAL NOTE

# Measuring energy response for RTQA Radiochromic film to improve quality assurance procedures

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## Abstract

RTQA Gafchromic, radiochromic film is assessed for its radiation energy dependence in photon beams ranging from superficial to megavoltage energies. RTQA radiochromic film has uses in radiation quality assurance procedures due to its auto development and visualisation properties. These properties allow for immediate comparison of x-ray alignment and coincidence not available with radiographic films. Results show that the RTQA film produces an energy dependant darkening to x-rays which results in x-ray energies of 69 keV photon equivalent (150 kVp) to produce 2.14 times the optical density to dose ratio of a 6MV x-ray beam. The following dose ratio's (normalized to 1 at 150kVp) provide the same net optical density change for RTQA film. 1.47 – 50 kVp : 1.21 – 75 kVp : 1.09 – 100 kVp : 1.01 – 125 kVp : 1.00 – 150 kVp : 1.03 – 200 kVp : 1.07 – 250 kVp : 2.14 - 6 MVp : 2.14 10 MVp. Although the film is not designed to be used as a quantitative measure of radiation it is still useful to know its energy response at differing x-ray energies to expose the film to the appropriate dose to provide optimal darkening characteristics for a given QA test at the appropriate energy. Our results have shown that a 0.3 optical density change with RTQA film provides a colour change level useable for accurate alignment procedures

**Key words** Radiochromic film, Gafchromic RTQA, radiation dosimetry, energy dependence

## Introduction

Some quality assurance procedures in radiation therapy require a qualitative rather than quantitative analysis of radiation dose deposition. Examples of such procedures could include x-ray versus light field alignment for megavoltage x-rays or cone placement / x-ray alignment for superficial treatments. These types of procedures have conventionally been performed with radiographic films. In this process, the film needs to be aligned and then marked with either a high density material (lead wire or pellets) or a small puncture mark to align the field or treatment cone to the x-ray field delivered. As radiographic film needs a development process it is then required to be taken away from its original position and developed before a result is found. This can be a time consuming and often tedious process especially if multiple films are required and misalignments can only be seen post processing. Another consideration is the energy dependence of radiographic films which can be anywhere from 14 to 25 times more sensitive at kilovoltage energies compared to megavoltage energies[1,2,3] . Thus, to produce a relatively similar optical density picture for each beam energy analysed, significantly different doses are required which can add to the complexity of the QA process. In comparison a relatively new film product called RTQA Gafchromic is a radiochromic film product specifically designed for use in a qualitative approach for radiotherapy x-ray quality assurance. Its manufacturer described properties of immediate darkening and easy visualisation should make this film well suited for quality assurance procedures where a qualitative result is required. Also the film can be easily cut to size which has a substantial practical advantage over radiographic film. Thomas et al[4] showed that RTQA can be used as a high energy QA tool. The purpose of this work is to examine the energy dependence of the film to ascertain the variations in applied dose that will be required to produce similar optical density results for qualitative procedures and to examine the sensitivity of the film for different energy beams.

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## Materials and methods

Gafchromic RTQA (ISP Corp, Wayne NJ, USA) radiochromic film is studied for energy and dose dependence to x-ray radiation at radiation therapy dose levels in this work. RTQA is constructed differently to most

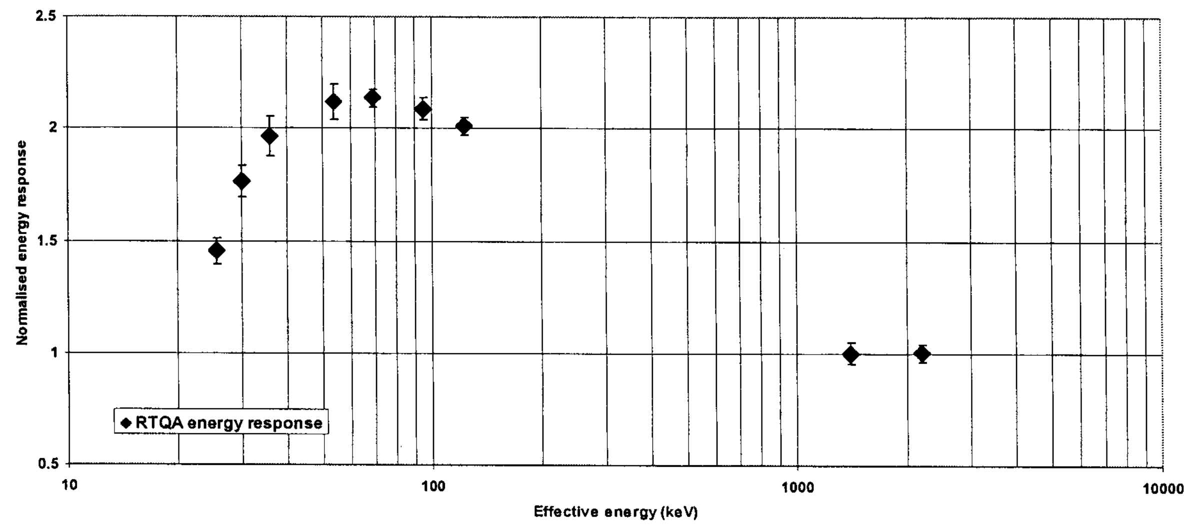


**Figure 1.** *Energy response characteristics of RTQA Gafchromic radiochromic film normalised to 1 at 6MV x-ray energy.*

| Peak energy (kVp) | Photon equivalent energy (keV) | Depth of irradiation (cm) | Energy response ratio |
|---|---|---|---|
| 50 | 25.5 | 0 | 1.45 ± 0.06 |
| 75 | 30.0 | 0 | 1.76 ± 0.07 |
| 100 | 36 | 0 | 1.96 ± 0.09 |
| 125 | 54 | 0 | 2.11 ± 0.08 |
| 150 | 69 | 0 | 2.14 ± 0.04 |
| 200 | 95 | 0 | 2.09 ± 0.05 |
| 250 | 123 | 0 | 2.01 ± 0.04 |
| 6000 | 1400 | 1.5 | 1.00 ± 0.05 |
| 10000 | 2200 | 2.5 | 1.00 ± 0.04 |

other Gafchromic film products in that it has an opaque white backing material and a yellow coloured transparent front polyester cover, both of which are 97 microns thick (ISP web page 2008)[5]. The film is designed this way to enhance the visual colour change caused by incident radiation. The active layer is 17 microns thick and also incorporates an adhesive layer within its design. The film used was from batch no. M0130RTQA10.

For dose delivery, the films were positioned in a solid water[6] phantom of dimensions 30cm x 30cm x 30cm. The phantom was placed on a Gulmay[+] D3300 orthovoltage machine and a Varian 2100C linear accelerator and films were given various absorbed doses up to 5Gy.Irradiations were performed at the position of Dmax for each beam. This was at the surface for the kilovoltage beams, 1.5 cm for 6 MV and 2.5 cm for 10 MV. The phantom size used provided ample backscatter material for full scatter conditions. The effective energies of each beam type were calculated from Half Value Layer measurements. All films were analysed using a PC desktop scanner and Image J software on a PC workstation at least 24 hours after irradiation to minimize effects from post irradiation colouration[7]. The scanner used for quantitative energy and dose response analysis was an Epson Perfection V700 photo, dual lens system desktop scanner using a scanning resolution of 150 pixels per inch. The images produced were 48 bit RGB colour images. An area of 1 cm x 1 cm was used to analyse the pixel values of the film. No filters or correction functions were applied to raw pixel value results. These images were analysed using the red component. Net Reflective optical density (ROD's) for all films were calculated to evaluate energy and dose responses. Net ROD is defined as equation 1 : -

$$\text{Net ROD} = \log (P_u/P_t) \qquad (1)$$

Where $P_u$ is the pixel value of the reflected intensity through an unexposed film and $P_t$ is the pixel value of the reflected intensity through an irradiated film. This method using one batch of RTQA film produced an uncertainty of measured dose of ± 4% (2SD) in the range of doses measured.

## Results and discussion

Figure 1 shows the normalised energy response of RTQA radiochromic film over the energies tested which ranged from 50kVp up to 10MV. Results are also shown in table 1 for clarity. The errors bars shown are the result of the variations in measured energy response at 4 dose levels

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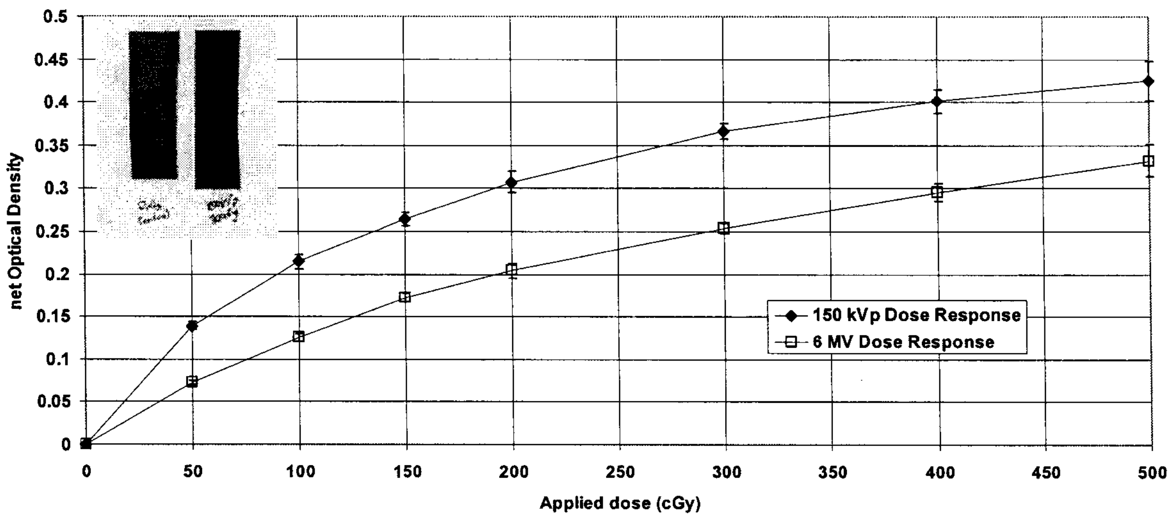


**Figure 2.** *Figure 2 shows the characteristic dose response of RTQA radiochromic film at 2 select energies showing the colouration variation that can occur per unit dose. Inset are two films, one exposed to 200cGy at 150 kVp and the other is unexposed.*

(50 cGy, 100 cGy 200 cGy and 400 cGy) and the uncertainty in measured optical density with a 95 % confidence level. Results were confirmed by applying the energy response data to each beam energy and applying different dose levels to the films again to produce the same optical density change. As can be seen by figure 1, a variation in dose to optical density response is seen with energy and the 69 keV photon equivalent (150 kVp) beam producing the highest level of optical density change per unit applied dose. The higher energy beams of 6MV and 10MV produced the lowest change in OD. A factor of 2.14 between the highest and lowest response was seen. This is significantly less than the 14.5 times difference for X-Omat V radiographic film[3]. Thus the following dose ratio's (normalized to 1 at 150kVp) provide the same net optical density change for RTQA film for quality assurance procedures. 1.47 – 50 kVp : 1.21 – 75 kVp : 1.09 – 100 kVp : 1.01 – 125 kVp : 1.00 – 150 kVp : 1.03 – 200 kVp : 1.07 – 250 kVp : 2.14 - 6 MVp : 2.14 10 MVp. Although the film does produce a degree of darkening variation as a function of beam energy it is substantially less than its radiographic counterparts. It must be noted that the magnitude of the energy response of this RTQA film is different to other Gafchromic film products such as EBT [3,8] and MD-55-2[9,10] which have a smaller energy response. It has similar characteristics in energy response to products such as Gafchromic XR – T[11] and XR - R[12] but the magnitude is smaller. Gafchromic film products have varying amounts of high atomic number dopants which affect the energy and sensitivity response of the film to produce optimal radiation measurement characteristics for their designed applications. This produces differing sensitivity and energy response characteristics between the various Gafchromic film products in ISP's range. This still may be of consequence and needs to be taken into account for delivery and qualitative analysis of film exposures used to verify beam alignment or the like. The degree of darkening of a film can change the appearance of a beam edge due to saturation levels and interpretation of the physicist. Using a similar optical density level for analysis at each beam energy minimises the impact of such conditions. This becomes a much easier process if the energy dependence of the film is significantly small as is the case for RTQA film.

Figure 2 shows typical dose response curves for RTQA film at beam energies of 150 kVp and 6 MV energy. As can be seen the relative response is non linear and at around the 2 Gy applied dose levels the net change is approximately 0.3 OD and 0.2 OD for 150 kVp and 6 MV x-rays respectively. A relative optical density change of 0.3 OD produces a significant visual colour change. At this level of OD change, x-ray field edges are well defined and easily measurable to sub millimetre level. A 0 net OD and 0.3 net OD film are inset into figure 2 for visual comparison. Although this picture is not in colour it represents the visual variation seen. We would recommend that colour changes of approximately 0.3 OD are required for accurate quality assurance procedures. One of RTQA's greatest advantages is the increase in time efficiency in its use for these type of QA procedures. By removing the complex marking procedure needed for radiographic film which is replaced by simple permanent marker dots and removing the processing time the average x-ray versus field alignment procedure takes approximately 2 minutes instead of the 10 to 20 minutes previously required. It can also provide a significant cost saving where multiple exposures can be performed with the same film piece in serial application. Figure 3 shows a RTQA film used for testing x-ray versus field sizes of 2 cm, 5 cm, and 10cm diameter circles with the exposures performed in series using the same film piece and without the need for processing. This procedure is much more difficult to perform with radiographic film with the 3 overlapping fields sometimes interfering with the ability to differentiate field edges of the inner beams. It

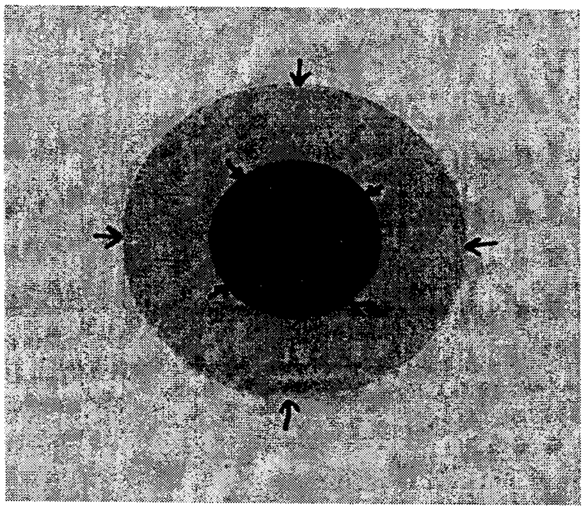

**Figure 3.** *Typical quality assurance film exposure at 150 kVp using RTQA for radiation field versus cone alignment tests which develop automatically and the film can be used repeatedly producing a cost and time saving.*

highlights the versatility of RTQA film for qualitative procedures. The film shown in figure 3 was irradiated in 3 steps with the alignment quality assurance check performed after each stage. In this way, the field edge for each cone or field is very easily defined and is not obstructed by the other fields in any way. RTQA film is not designed as a quantitative dosimeter for radiotherapy applications. That is left to its more energy independent sibling, EBT Gafchromic film. However the film during testing provided a relatively constant optical density to dose response within 4 % (2 SD of the mean) and as such does not vary considerably. Testing was not available on another batch so these results may not be applicable to inter-batch sensitivity however, quality assurance calibrations should always be performed on any new batch of film used whether it be radiochromic or radiographic.

## Conclusion

RTQA Gafchromic film is an alternative film which can be utilised for radiotherapy QA procedures and provides some advantages over commonly used radiographic films. These advantages include its lower energy dependence which means it can be more easily used over the extended energy range from kilovoltage to megavoltage x-ray beams with an order of magnitude less difference in the applied dose required for a similar optical density change. As it is automatically developing, it can be analysed in position on the accelerator or superficial machine which provides a significant time efficiency gain and increases easy of calibration procedure and finally it can be used for multiple exposures in series to provide improved time efficiency compared to radiographic film.

## Acknowledgements

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