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ORIGINAL PAPER

# Scanning orientation and polarization effects for XRQA radiochromic film

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**Abstract** Gafchromic XRQA radiochromic film, is an effective tool for quality assurance and dose assessment in kilovoltage radiotherapy and diagnostic applications. Like other Gafchromic film products, XRQA film exhibits a variation in dose to reflected optical density response with angle of rotation when analysed with a light source that is partially or fully polarised such as a desktop scanner. Although warnings are not given on manufacturers specifications, this can affect dosimetry accuracy and we recommend that it is essential to scan all XRQA films in the same orientation. The effect is not as pronounced as EBT Gafchromic film. The magnitude of this variation has been measured and shown to be up to $16 \pm 2\%$ (1SD) using a fully linear polarised light source was seen with a 90° angle rotation. This would be the maximum variation seen on a desktop scanner with a fully polarised light source. For our standard desktop scanner (Epson v700) a mean variation of $2 \pm 1\%$ from 0 cGy to 20 cGy applied dose was measured as compared to $8 \pm 2\%$ for EBT Gafchromic. We recommend that to decrease uncertainty in dose measurement, accurate alignment of the calibration films to experimental films be performed on a regular basis. This is especially important if your desktop scanner has a high degree of polarization of its light source.


## Introduction

For 2-dimensional quality assurance procedures and dosimetry analysis in diagnostic and therapeutic applications, radiochromic film has become an effective tool. As these films are automatically developing they remove the need for darkrooms and any form of processing post-irradiation. The most common method of analysis for

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radiochromic films is with the use of a flat bed scanner [1–4]. This is due to, the ease of use and the high accuracy achievable with a relatively inexpensive scanner model. Many authors have investigated various effects and uncertainties which are introduced with the use of such scanners. One aspect is the fact that most desktop scanners due to their intrinsic design with either reflected or transmitted light sources through glass plates, produce a partially polarised light source. Authors have investigated these effects on films such as EBT Gafchromic and MD-55-2 Gafchromic films and have measured differing levels of variation in measured reflected optical density with angle of orientation of the film with the scanner plate. Variations up to 50% have been measured with fully polarised light sources and EBT Gafchromic film [2,5]. The differing quantity of variation quoted in the literature is most likely due to the degree of polarization occurring with the different types scanners. XRQA film is a type of reflectance dosimetry film which has been developed for analysis at low kilovoltage energies and low applied dose levels [6–9]. Examples where low applied dose measurements are of importance include estimation of doses to the eye lens behind eye shields or doses behind nasal shields in superficial facial radiotherapy. The films physical design is different from the transmission style films in that an opaque backing material is used so that the film can only be analysed in a reflective type manner. The film also incorporates a yellow coloured filter to aid in visual recognition of colour change at small doses. The aim of this study is to examine the effects on measured reflected optical density of scanner orientation for this film with semi-polarised and polarised light sources to examine if variations occur in measured reflected optical density with angle of orientation in order to improve accuracy of XRQA radiation dosimetry.

## Materials and methods

Experiments were performed with radiochromic film type Gafchromic XRQA Lot# 36124-002 (ISP Corp, Wayne NJ, USA) to analyse the effects of film to scanner orientation with semi-polarised and polarised light sources. Gafchromic XRQA film is constructed with a multi-layer approach consisting of the active polymer along with polyester protective coatings which are utilized for a few features. The base coat polyester is a white opaque coating which is used to reflect the active layer colour change for visual inspection. The top polyester coating is a transparent yellow coloured filter which acts to protect the active layer and provide an enhanced visible colour change for the film upon radiation for qualitative QA procedures. As the base coat is opaque, the film can only be analysed using a reflective mode of analysis. This can be most easily performed using a desktop scanner.

To measure the variation in reflected optical density with respect to angle of film orientation of XRQA Gafchromic film with polarised light, a greater than 99% linear polarised light source was utilized. The polariser used was a linear polarised Kodak sheet ($10\,\mathrm{cm} \times 20\,\mathrm{cm}$) and produced a reduction in transmitted light of 99.8% when two pieces are positions normal to each other's axis of polarization. Measurements were also made without the linear polarizing sheet to ascertain the effect caused by just the scanner alone. The linear polariser sheets when used were positioned parallel to the scanning axis within $\pm 1^\circ$. The films were analysed 1 day after irradiation to minimize post-irradiated coloration effects [10]. The films were cut into $10\,\mathrm{cm} \times 10\,\mathrm{cm}$ squares using sharp scissors with the analysis performed at the centre of each film piece to avoid any optical damage which may occur due to the cutting process [11]. Measurements were made for reflected optical density over a $360^\circ$ rotation of the film in incremental steps of $10^\circ$. The films orientation was defined as $0^\circ$ when the film piece was in "landscape mode" and with the upper surface of the film, when removed from the commercial packaging, remaining the upper surface for analysis. The scanner used was an Epson V700 desktop scanner in reflective mode.

For dose delivery, the films were positioned in a solid water [12] phantom of dimensions $30\,\mathrm{cm} \times 30\,\mathrm{cm} \times 30\,\mathrm{cm}$. The phantom was placed on a Gulmay (Gulmay Limited, Chertsey, Surrey, KT16 9EH, United Kingdom) D3300 orthovoltage machine using a 10 cm diameter circular field and films were given absorbed doses from 0 cGy to 20 cGy. Irradiations were performed at the surface, position of Dmax for the 100 kVp beam. All films were analysed using a PC desktop scanner and ImageJ [13,14] software on a PC workstation. The scanner used for quantitative analysis was an Epson Perfection V700 photo, dual lens system desktop scanner using a scanning resolution of 50 pixels per inch in reflection mode [15]. The images produced were 48 bit RGB colour images. An area of $3\,\mathrm{cm} \times 3\,\mathrm{cm}$ 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) for all films was calculated to evaluate energy and dose responses. Net ROD is defined as Eq. (1):

$$\mathrm{Net\,ROD} = \log(P_\mathrm{u}/P_\mathrm{t}) \qquad (1)$$

where $P_\mathrm{u}$ is the pixel value of the reflected intensity through an unexposed film at an orientation whereby the maximum pixel value is found and $P_\mathrm{t}$ is the pixel value of the reflected intensity at any other film orientation or irradiation level. Ohuchi [16] produced a similar definition for reflected optical density. For RXQA film this was found to be at approximately $-10^\circ$ ($80^\circ$). The errors and uncertainties of results are the average of five film pieces used at each data point and measured five times each for average pixel value. Results are quoted to 1SD of the mean.

## Results and discussion

Fig. 1 shows the variation in normalised net reflected optical density of XRQA film at various absorbed radiation doses (0 cGy, 10 cGy and 20 cGy) when analysed using a Epson V700 desktop scanner in normal scanning mode. Results are normalised to 1 at the maximum net reflected optical density measured for each film dose level. The absolute values for net reflected OD values were 0.205, 0.505, 0.785 at $-10^\circ$ orientation for 0 cGy, 10 cGy and 20 cGy respectively. As can be seen there is a small but