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# Evaluation of a fluorescent light densitometer for radiochromic film analysis

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**Abstract**

Radiochromic film dosimetry used in high energy X-ray detection has been evaluated using a VIDAR VXR-12 digitiser for accuracy and results are compared to other densitometers. The VIDAR scanner uses a broad band fluorescent light source which however, produces a negligible ultraviolet reaction effect on the radiochromic film with an estimated equivalent dose of 0.25 cGy darkening per scan to MD-55-2 film. By varying the exposure setting on the scanner, more accurate information can be obtained using radiochromic film within a certain optical density range. Over the range of 0–20 Gy, the scanner can accurately measure dose with a standard deviation of 1.8% calculated between the measured values and a polynomial fit to data. The VIDAR scanner is shown to be a suitable densitometer for radiochromic film. © 2002 Elsevier Science Ltd. All rights reserved.

## 1. Introduction

The VIDAR VXR-12 scanner (VIDAR, 1997) produces images in 4096 (12 Bit) or 256 (8 Bit) levels of Gray. It has a minimum pixel size of 85 μ*m* and can also be scanned at 169, 339 and 423 μ*m*. During image capture the film is passed over a fluorescent light and the image is focused on a 5000 element CCD array through a focusing lens. Optical density range is quoted by the manufacturer as 0–2.6 OD. This digitiser has been shown to be an adequate densitometer for radiographic film analysis by Mersseman and De Wagter (1998) and we expand on their work to assess the scanners ability to measure radiochromic film and analyse sources of errors highlighted in their note. Scans of film were made using generated tables and a user defined linear histogram function which was designed to limit the measured optical density range to that of the irradiated radiochromic film. Measurements were also compared to a 670 nm spot densitometer (Butson et al., 1999) and a Scanditronix RFA-300 densitometer converted to read at 660 nm (Carolan et al., 1997).

## 2. Materials and methods

Measurements were performed with a Varian 2100C linear accelerator using 6 MV X-rays, in a solid water, (Constantinou et al., 1982) stack phantom and with MD-55-2 Gafchromic film [1] (batch no. lot # 37350) placed at 1.5 cm depth. The Gafchromic film was sandwiched in between the slices to measure at depth. Recommendations outlined by TG-55 (Niroomand-Rad et al., 1998) were observed and used when handling the Gafchromic film. The calibration results were achieved by irradiating the films in 1 Gy intervals from 1–20 Gy at $D_{\max}$ using a 10 cm × 10 cm field size 100 cm SSD with a single exposure. The single exposure was used as the batch had previously been tested for non-uniformity and was found to be ±3% over the film sample. Tests were carried out to compare the VIDAR scanner to other tested densitometers for radiochromic film

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analysis. To measure the effects of the VIDAR's fluorescent light source on the radiochromic film, a 3 cm × 3 cm piece of unirradiated Gafchromic film was scanned through the system, with default exposure settings, 200 times. To do this, the Gafchromic film was attached with tape to the side of a piece of unirradiated but processed radiographic film. It is estimated that the 3 cm × 3 cm Gaf film, from edge to edge is in the light source for approximately 1.5 s per scan. An estimate of the temperature inside the scanner, where the Gafchromic film would be located during readout was tested using a fluke 80 TK thermocouple module. The estimated temperature was measured as $30 \pm 2^{\circ}$C with the ambient temperature at $21^{\circ}$C. The films optical density was measured using the spot densitometer (670 nm) in 50 scan intervals to assess the effect of the fluorescent light source. A control film was also left in the ambient light next to the scanner to measure any effects of background light on the Gafchromic film. The measured results are a subtraction of the control film from the scanned film. After 200 scans, the film had received an equivalent of $0.5 \pm 0.2$ Gy from the scanning system. This results in an approximate effect of 0.25 cGy darkening per scan which can be considered a negligible effect.

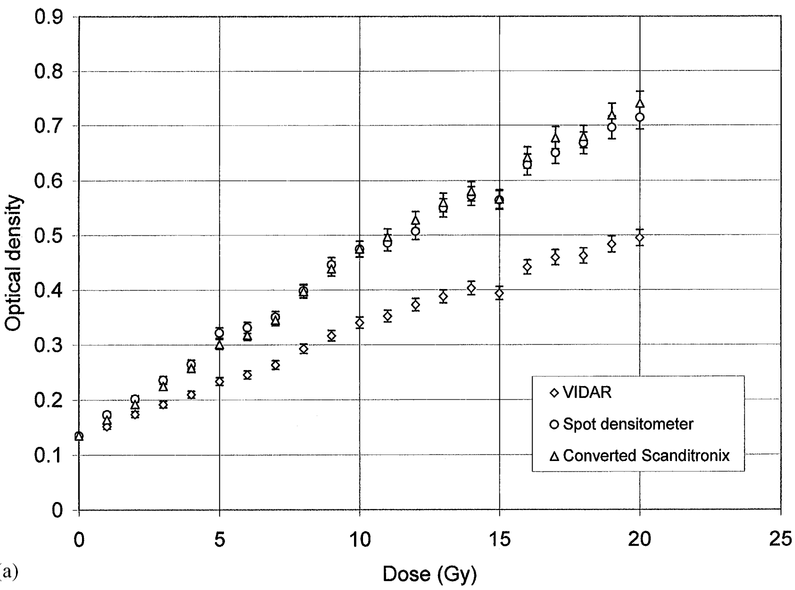
The film results were evaluated using two computer software packages. Raw data were collected using the Osiris imaging software from the university of Geneva, Switzerland. These raw data were then sent to Microsoft excel for evaluation. The optical density was calculated using a second order polynomial function which was fitted to results for calibrated standard optical density films. The effects from neighbouring film optical density was tested for radiochromic film analysis. In essence, we wished to see if adjacent areas of film with large contrasts in optical density would effect the absolute optical density reading obtained for the same radiochromic film. To perform this task, 30 cm × 40 cm sheets of exposed Kodak X-Omat V radiographic film was used as the background/adjacent film material. The same 3 cm × 3 cm pieces of radiochromic film were inserted into holes cut from the centre of each of the radiographic films. The radiographic films were uniformly exposed to produce various optical density levels ranging from 0.03 to 3 OD which is assumed to cover the range of all clinical films used. The radiographic/radiochromic film was scanned each time to evaluate if any changes in absolute OD were measured on the radiochromic film due to the changed conditions around it.

## 3. Results and discussion

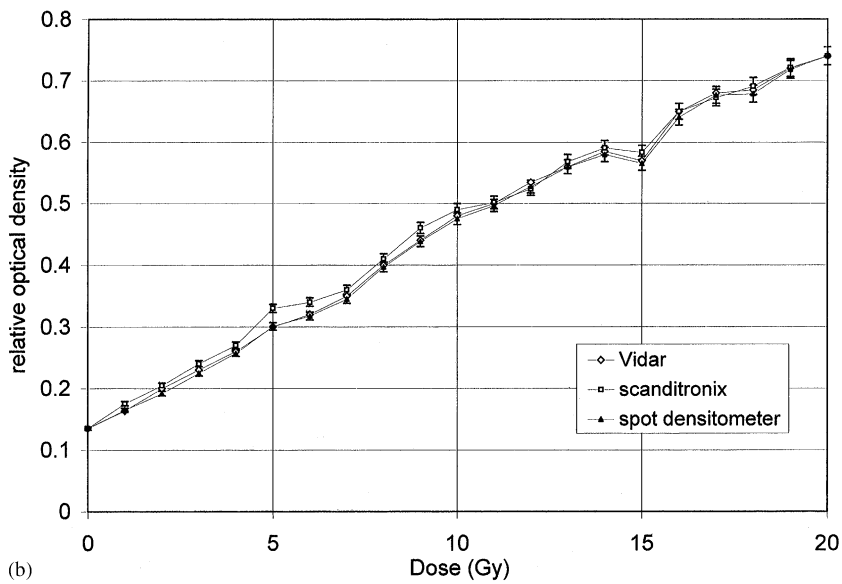
Fig. 1a shows the absolute optical density dose response of the Gafchromic film from 0 to 20 Gy for 6 MV X-rays as measured with the VIDAR VXR-12, the converted Scanditronix and our own spot densitometer. As can be seen, the devices with readout wavelengths which lie near the peak of the absorption spectra for the Gafchromic film produce a higher OD to dose ratio by approximately a factor of 2 with the net OD for the 20 Gy being 0.36 for the VIDAR and 0.605 with the spot densitometer. Results show a high level of reproducibility for the VIDAR scanner as the same films scanned 10 times over a period of 5 days showed a variation in OD for an averaged 1 cm × 1 cm area in the centre of the film of less than 1%. Variations in pixel to pixel values, however, ranged up to 6% for one piece of the film.

Fig. 1b shows the calibration curves produced by the VIDAR VXR-12, the Scanditronix RFA-300 converted scanning arm system, and the spot densitometer. All curves have been normalised between the initial optical density and end optical density of the spot densitometer for comparison. This has been performed as the optical density values produced by each densitometer is different due to the different light sources used. The error bars shown in Fig. 1 are 1 standard deviation of the mean result averaged over a 0.5 cm × 0.5 cm square at the centre of each 1 cm × 1 cm piece of the Gafchromic film. This was achieved by selecting a region of interest for the VIDAR scanner, by scanning 4 profiles over the 0.5 cm square using the Scanditronix and by taking 10 measurement over the 0.5 cm square using the spot densitometer. The standard deviation in measured optical density over all films was 1.8% with the largest deviation between the three densitometers being 5.5%. As the normalised optical density to dose response for the three detectors used could vary depending of the spectral wavelengths of their respective light sources, the variations seen would not be considered unusual.

Table 1 shows the OD results obtained from an unirradiated piece of the Gafchromic film and a 20 Gy irradiation with varying levels of background optical density material in place. Backgrounds varied from 0.03 to 3 OD. Results show the optical density measured for the radiochromic film at the quoted distances from the boundary between the radiographic film and the radiochromic film. Results showed that the background produced very small effects on the measured optical density for the Gafchromic film. The averaged optical density at the centre of the film with one standard deviation was $0.175 \pm 0.003$, $0.175 \pm 0.003$, $0.176 \pm 0.003$, $0.177 \pm 0.003$ for 0.03, 0.2, 0.5 and 3.0 backgrounds, respectively. This relates to an approximately 1% increase in optical density for the unirradiated film but within the error limits of the measurement. For the film irradiated to 20 Gy, the results were $0.531 \pm 0.012$, $0.531 \pm 0.091$, $0.533 \pm 0.015$, $0.535 \pm 0.012$ which relates to a 0.7% increase in OD, well within the standard deviation over the film piece. These results show that highly contrasting film optical densities produce a minimal effect on the Gafchromic film dosimetry using the VIDAR scanner which are within mean errors in measurement for OD readings. These results differ from Mersseman and De Wagter (1998) who measured deviations up to 7.5 cm away from the film edge when measuring radiographic film. We assume that the difference in results




(a)




(b)

Fig. 1. (a) Optical density versus dose response curves for the Gafchromic film as measured using the VIDAR scanner, a 670 nm spot densitometer and a 660 nm converted Scanditronix densitometer. The VIDAR scanners response is much lower than the other two systems, however, still produces accurate results. (b) Comparison of the normalised optical density measurements for three radiochromic film readers, the VIDAR VXR-12, a converted Scanditronix RFA-300 and a spot densitometer.

is accountable from the initial intensity level of the VIDAR scanners light source. When the light source intensity is set at a low level which produces optimal optical density readout for the Gafchromic film (OD range within 0.1–1), the intensity of the light source does not saturate the CCD camera elements to the extent that charge flows from the saturated elements to surrounding elements. Nor does it initiate scattering of light through and off the film as is the case for readout of high OD radiographic film, which effects OD measurements for surrounding areas.

## 4. Conclusions

The VIDAR VXR-12 film digitiser is an adequate densitometer for accurate analysis of radiochromic film.

Table 1
Effects on the optical density of radiochromic film with various high contrast areas in close proximity

| Distance from boundary (mm) | Background level (OD) | | | |
|---|---|---|---|---|
| | 0.03 | 0.2 | 0.5 | 3.0 |
| *Optical density* (0 Gy *film*) (*one standard* deviation ± 0.003) | | | | |
| 2 | 0.173 | 0.175 | 0.0177 | 0.179 |
| 5 | 0.174 | 0.175 | 0.177 | 0.178 |
| 10 | 0.175 | 0.175 | 0.176 | 0.177 |
| 15 | 0.175 | 0.175 | 0.176 | 0.177 |
| *Optical density* (20 Gy *film*) (*one standard* deviation ± 0.012) | | | | |
| 2 | 0.529 | 0.531 | 0.534 | 0.537 |
| 5 | 0.530 | 0.531 | 0.534 | 0.537 |
| 10 | 0.531 | 0.531 | 0.533 | 0.536 |
| 15 | 0.531 | 0.531 | 0.533 | 0.535 |

Negligible colouration is seen by the fluorescent light source for film scanning and the results agreed with other densitometers within 1.8% on average. By using lower light source levels as required for radiochromic film analysis, background material or areas of high contrast on the film produce a minimal effect on dosimetry results.

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## References

Butson, M., Yu, P., Cheung, T., Carolan, M., Arnold, A., Quach, K., Metcalfe, P., 1999. Dosimetry of blood irradiation with radiochromic film. Transfus. Med. 9, 205–208.

Carolan, Butson, Herrmann et al., 1997. Conversion of an infrared densitometer for radiochromic film analysis. Aust. Phys. Eng. Sci. Med. 20, 185–189.

Constantinou, C., Attix, F.H., Paliwal, B.R., 1982. A solid water phantom material for radiotherapy X-ray and gamma ray beam ray calculations. Med. Phys. 9, 436–441.

Mersseman, B., De Wagter, C., 1998. Characteristics of a commercially available film digitizer and their significance for film dosimetry. Phys. Med. Biol. 43, 1803–1812.

Niroomand-Rad, A., Blackwell, C., Coursey, B., Gall, K., Galvin, J., McLaughlin, W., Meigooni, A., Nath, R., Rodgers, J., Soares, C., 1998. Radiochromic film dosimetry: Recommendation of AAPM radiation therapy task group 55. Med. Phys. 25, 2093–2115.

VIDAR, 1997, VIDAR VXR-12 Digitizer Manual. VIDAR Systems Corporation, Herndon, VA 20170.