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NOTE

Use of a blood glucose meter for radiochromic film analysis in blood irradiation

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Abstract

The use of a diabetic blood glucose meter for radiochromic film dosimetry in blood irradiation using x-ray beams on a medical linear accelerator has been investigated. The glucose meter provides optical density analysis in the visible and infrared region using a reflectance measurement technique. By comparing the 'blood sugar' level output with standard calibration gafchromic films a calibration curve is produced for quantitative analysis. Results show that a reproducible dose to meter output curve can be fitted using a second order polynomial function and that blood irradiation doses *in vitro* were measured to within 7.9% mean error (as compared to ionization chamber results) using the blood glucose meter. This level of accuracy falls below that measured with a standard densitometer (4.3%); however, results show that the blood glucose meter, which would be available in any haematology department, produces an adequate measure of gafchromic film optical density for blood irradiation dosimetry.

1. Introduction

Various dosimetry techniques are used to measure dose to blood products. These include thermoluminescent dosimeters (TLDs), alanine, ferrous sulphate, red perspex, metal oxide semiconductor field effect transistors (MOSFETs), chloroform/dithoizone/paraffin mixture (Hillyer *et al* 1993) and radiochromic film (Butson *et al* 1999). Radiochromic film is a useful dosimeter in blood irradiation in that it not only provides quantitative information about the dose received but also acts as a visual reminder that the blood has been irradiated. Blood products are irradiated to diminish the risk of transfusion-associated graft versus host disease (TA-GVHD). The desired effect of irradiating the blood is to inhibit lymphocyte function and therefore to prevent GVHD while not causing damage to platelets and other blood fractions.

Guidelines based on the work of Pelszynski *et al* (1994) and Luban *et al* (1996) state that at least 25 Gy provides a 5 log depletion of T cells in a T cell cologen assay, sufficient for the elimination of GVHD. This note investigates the novel use of a visible/infrared light reflectance blood glucose meter for quantitative analysis of radiochromic film dosimeters used in blood irradiation and compares the results to a standard radiochromic densitometer for accuracy.

2. Materials and methods

For the analysis of gafchromic film irradiated optical density versus dose, a Betachek (National Diagnostic Products Pty Ltd, Gordon, Australia) LYNX blood glucose meter was investigated. The Betachek LYNX meter is designed for the analysis of blood glucose levels with the aid of test strips which turn a blue and purple colour after contact with the patient's blood. The instrument measures light reflectance from the strip and converts the digital signal into a blood sugar level in mg dl^{-1} and displays the results on the screen ranging from 9 to 460 mg dl^{-1}. The sensitivity of the meter can be changed by using programmed values which are used to originally calibrate the chemical reactions on the test strips with ten levels of variation. A lower sensitivity gives the largest range of results for dose analysis. The meter uses dual light sources for reflectance measurements. One of them is red/infrared and the other is green for analysis. The film used for analysis was gafchromic MD-55–2 with batch number 970116. Precautions in handling of radiochromic film outlined in TG-55 (Niroomand-Rad *et al* 1998) were taken. During experiment storage and film analysis the film was kept at temperatures of 22 °C ± 2 °C thus reducing the effects of time and temperature-dependent evolution and readout (Meigooni *et al* 1996) of the absorption spectra of the film. The film is only removed from a light tight envelope during irradiation and readout to reduce the effects of ambient light (Butson *et al* 1998). To measure results for gafchromic film darkening, the gafchromic film was cut into strips of the same dimensions as the blood test strips and inserted into the reader with a control 'white backing' material to aid in the reflectance process. The strip dimensions were 0.5 cm wide by 4 cm long. The thickness of the gafchromic film is approximately the same as the test strips, which allows easy insertion. Calibration gafchromic films were irradiated in a solid water phantom to doses ranging from 20 Gy up to 40 Gy in 2 Gy intervals to measure the dose response to meter reading. Ten films were used for each absorbed dose level for reproducibility of results. From these calibration curves *in vitro* results for blood irradiation doses were analysed and compared to densitometer readings using a Vidar VXR-12 densitometer for accuracy and reproducibility. Twenty *in vitro* measurements were made for comparison. Blood products are irradiated in a 40 cm × 40 cm × 31.5 cm Perspex 'blood box' which is filled with the blood products to be irradiated and bags containing rice during irradiation. For standard blood irradiation, a dual parallel-opposed field 6 MV treatment is used where the blood is placed in a 15 cm thick active volume, which is located in the centre of the blood box. Irradiations are performed using beams produced by a Varian 2100C medical linear accelerator. The blood is irradiated to an average dose of 30.6 Gy. During *in vitro* irradiations, the gafchromic films are placed as close as possible to the beams' central axis at the isocentre, which lies amongst the blood product bags being irradiated.

3. Results and discussion

Figure 1 shows the calibration curve for absorbed dose to meter reading using the LYNX meter and gafchromic film. The errors shown are two standard deviations of the mean for ten film

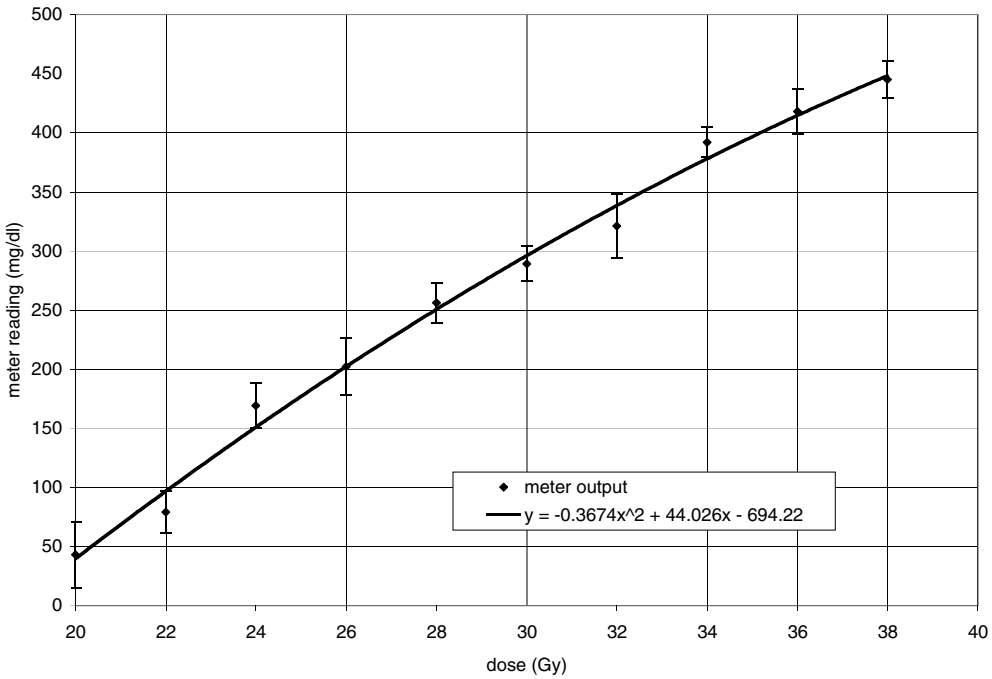

Figure 1. Calibration curve for dose versus meter output for gafchromic film and the blood glucose reflectance meter.

strips measured at each selected dose level. To produce better accuracy and reproducibility, a strip of plain white paper was placed directly behind the gafchromic film strips when inserted in to the reader. This produced a larger range of dose measurements within the meter's range as well compared to the results without a white strip. As the measurements are based on the reflectance of light from the film strips the white backing must produce a uniform reflective surface to assist with the reproducibility. The results show a slightly nonlinear result for absorbed dose to meter reading; however, a second-order polynomial fit can be applied to the results, which is given on the figure. Readings below 18 Gy and above 38 Gy were unattainable on this meter due to the limitations of the meter's output. When the recorded readings are below 9 mg dl^{-1} (below approximately 18 Gy on the film) the meter's output is recorded as 'low'. If the reading is above 460 mg dl^{-1} (above approximately 38 Gy on the film) the meter output is 'high'. This still provides an adequate range for dose measurements for blood irradiation. Figure 2 shows the measured *in vitro* results for 20 blood irradiations measured using an ionization chamber and gafchromic film, read out using the blood glucose meter and the Vidar densitometer. From these results, a mean error (average measured difference between the film results and the ionization chamber results) for the gafchromic film/blood meter is 7.9%. This is compared to 4.3% when the same films are readout using the Vidar densitometer. For error/deviation histogram results, using the blood meter, three results were taken by less than 4%, seven taken by 4%–8%, nine taken by 8%–12% and one taken by 12%–16%. Results have shown that the blood glucose meter does not produce as accurate results as the densitometer; however, the variations in measured dose would still be considered adequate for the assessment of blood irradiation dose quality assurance. A blood glucose meter is an inexpensive (less than $US50) mass-produced device, which would be available

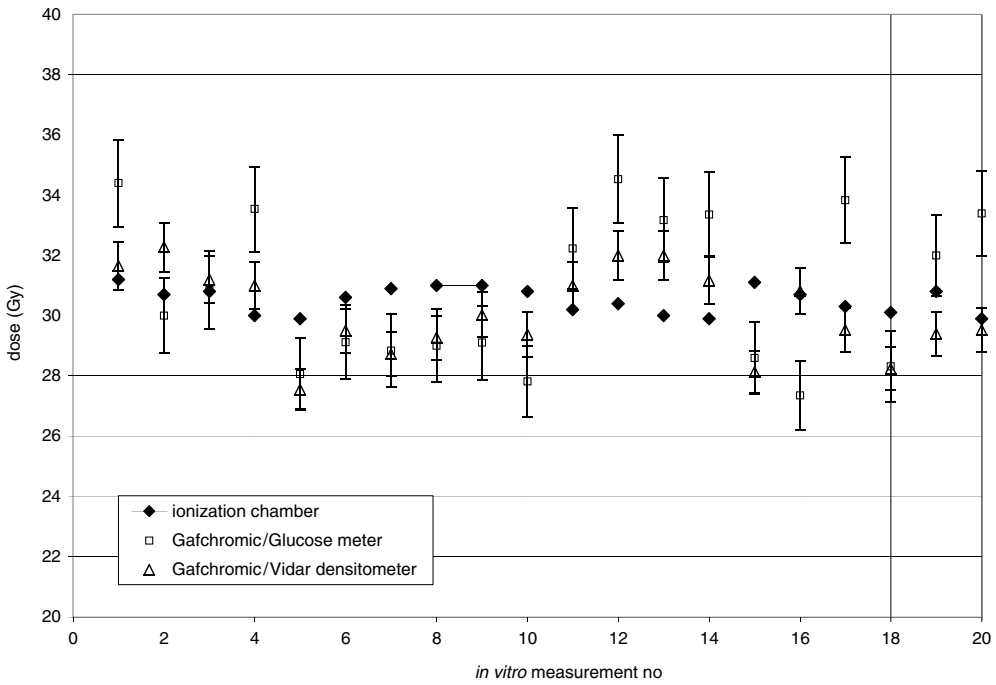

Figure 2. Measured doses *in vitro* for 20 blood irradiations. The results measured with the ionization chamber and gafchromic film read out by the blood meter and a Vidar densitometer.

in most haematology departments. This device can be used for the adequate measurement of doses with the gafchromic film dosimeter cut to the shape of the meter's test strips for blood irradiation procedures and would be useful for haematology departments wishing to monitor blood product irradiated doses independently.

4. Conclusion

A blood glucose meter which would be available in most haematology departments can be used as a densitometer for measurement of gafchromic film colour changes associated with absorbed radiation doses. The meter is useful in providing quantitative results for doses delivered from blood irradiation and measured *in vitro* doses within 7.9% mean error compared to ionization chamber results. This is an adequate level of measurement for blood irradiation doses and would be a useful device for haematology departments which irradiate blood for spot checks of delivered doses to blood products.

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References

Butson M, Yu P and Metcalfe P 1998 Effects of readout light sources and ambient light on radiochromic film *Phys. Med. Biol.* **43** 2407–12

Butson M, Yu P, Cheung T, Carolan M, Quach K, Arnold A and Metcalfe P 1999 Dosimetry of blood irradiation with radiochromic film *Trans. Med.* **9** 205–8

Hillyer C D *et al* 1993 Development of a colorimetric dosimeter for quality control of blood units and irradiators *Transfusion* **33** 898–901

Luban N L and DePalma L 1996 Transfusion-associated graft versus host disease in the neonate expanding the spectrum of disease *Transfusion* **36** 101–3

Meigooni A, Sanders M, Ibbott G and Szeglin S 1996 Dosimetric characteristics of an improved radiochromic film *Med. Phys.* **23** 1883–8

Niroomand-Rad A, Blackwell C, Coursey B, Gall K, Galvin J, McLaughlin W, Meigooni A, Nath R, Rodgers J and Soares C 1998 Radiochromic film dosimetry: recommendation of AAPM radiation therapy task group 55 *Med. Phys.* **25** 2093–115

Pelszynski M, Moroff G, Luban N, Taylor B and Quinones R 1994 Effect of gamma irradiation of red blood cell units on T-cell inactivation as assessed by limiting dilution analysis: implications for preventing transfusion associated graft versus host disease *Blood* **83** 1683–9