Measurement of skin dose using GafChromic XR Type-R film during low kv Intraoperative Radiotherapy for breast cancer

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Introduction

The past 20 years have seen a distinct shift in the approach to the treatment of breast cancer, away from radical interventions toward more conservative techniques. Randomised clinical trials have shown that breast conserving surgery allied to external beam radiotherapy compares favourably with more radical procedures such as mastectomy [1, 2].

Intraoperative radiotherapy (IORT), using an innovative miniature x-ray source to administer a single large fraction, avoids unnecessary treatment to the whole breast and delivers a critical dose to the tumour bed only.

Since a single large fraction is used, it is important to quantify the skin dose to identify areas where unwanted skin reaction could be expected.

Gafchromic XR Type-R film (GC-XRR) (International Specialty Products, Wayne, NJ) has recently been developed for the measurement of absorbed dose of low energy photons and has the added advantage that dose readout is a simple procedure [3].

Exposure to ionising radiation causes GC_XRR radiochromic film to immediately change colour and darken. The degree of darkening is proportional to exposure and can be quantified with a reflection densitometer or flatbed scanner.

The use of other methods of *in-vivo* dose determination such as TLDs, MOSFETs and diodes is more complex.

Materials and Methods

GC_XRR radiochromic film (Lot no. 34170-003B) was used for this study. It consists of three layers with a 97 µm top layer of translucent yellow dye, a 15 µm active middle layer and a 97 µm white, opaque base layer providing image reflection (Fig. 1). When the active component in the films is exposed to radiation, it reacts to form a blue coloured polymer with absorption maxima at about 615nm and 675nm.

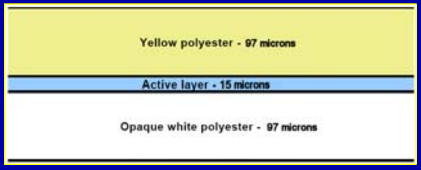

Fig. 1: Structure of GC_XRR Film

One purpose of the yellow dye is to enhance the visual contrast of the chromatic changes that occur when the film is exposed to radiation. A second purpose is to protect the active layer against exposure by UV and blue light and thereby enable the film to be handled in visible light.

The active component in GC_XRR film is a long-chain fatty acid, similar to stearic acid and belonging to a class of molecules known as diacetylenes. When exposed to radiation, active diacetylenes undergo a solid-state polymerisation reaction producing a blue coloured dye polymer referred to as a polydiacetylene.

A portable x-ray source (Carl Zeiss AG, Oberkochen, Germany) operating at 50 kV and 40 µA with a measured half-value layer of 0.11 mm Al was used to obtain a plot of the film response in terms of net reflection density versus absorbed dose from 1 to 10 Gy in increments of 1 Gy (Fig. 2). A reflection densitometer (X-Rite Inc., Grandville, MI) was used to read the optical density at each exposure.

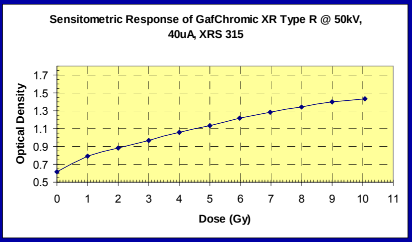

Fig. 2: Sensitometric Response of GC_XRR Film (Lot No. 34170-003B)

For increasing dose, the GC_XRR film undergoes a change from amber to a dark greenish black colour as shown in Fig. 3.

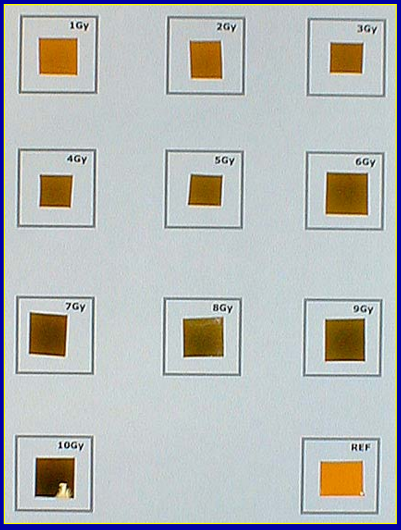

Fig. 3: Colour change in GC_XRR Film

To obtain the breast skin dose, four pieces of unexposed GC-XRR film each 1.5 cm x 1.5 cm were wrapped in sterile Tegaderm™ (3M Health Care, St. Paul, MN) film in the operating theatre before being placed by the surgeon concentrically around the wound site prior to irradiation.

The spacing of the films was intended to give an indicative value of the average skin surface dose (Fig. 4 and 5). After treatment, the optical density of the films was measured and the absorbed dose interpolated from the sensitometric response curve for that particular x-ray source.

Fig. 4: Arrangement of GC_XRR Film around Breast with Applicator inserted (pre-irradiation)

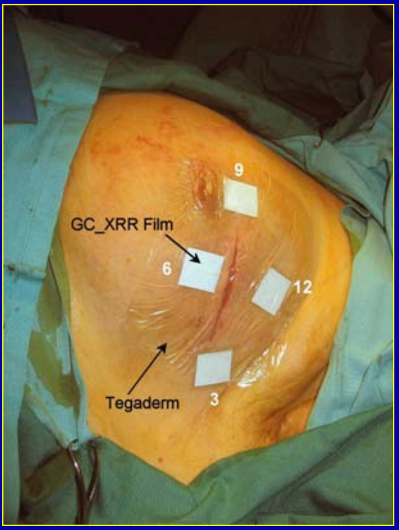

Fig. 5: Arrangement of GC_XRR Film around Breast (post-irradiation)

Results

We used GC-XRR film on fourteen patients (on going) in order to quantify breast skin dose during low kV IORT.

The prescribed dose was 5 Gy to a uniform 1 cm margin in tumour cavity after excision.

Treatment times ranged from 16.81 to 32.53 minutes (mean = 25.86) and the applicator sizes were 5.0 cm in two cases, 4.5 cm in eight cases, 4.0 cm in one case and 3.5 cm in three cases.

The absorbed doses ranged from 1.94 to 4.56 Gy with a mean of 3.04 Gy. This is comparable with TLD doses determined at an earlier stage of the Targit trial [4].

Conclusions

Initial results indicate that GC-XRR film is a useful tool for the determination of breast skin surface dose during low kV IORT.

It is easy to use in the operating theatre, requires no prior preparation, provides a direct read-out and has the potential to provide dose distribution information.

Due to its nature, thinness, flexibility, tissue equivalence and its ability to be cut and shaped to any size, GC_XRR film is an excellent tool for measuring breast skin dose during IORT.

References

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The authors wish to acknowledge the support of the *Ninewells Cancer Campaign* (Dr. J Wood MBE and Dr P McPherson OBE).