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# Weak energy dependence of EBT gafchromic film dose response in the 50 kVp–10 MVp X-ray range

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## Abstract

The energy dependence of the dose response of EBT Gafchromic film is assessed over a broad energy range, from superficial to megavoltage X-rays. The film is auto-developing and sensitive, it provides accurate dose assessment of low doses (about 1–2 Gy) used in radiotherapy. The energy dependence of the response of EBT film was found to be very weak: the variations do not exceed 10% over the range from 50 kVp to 10 MVp X-rays. By contrast, variations of the response of Gafchromic HS film are as big as 30% over the same range, and variations of the response of Radiographic film exceed one order of magnitude. This weak dependence provides significantly higher accuracy of dose measurements under conditions of varying spectral quality of X-ray beams, which are common in radiation therapy.

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**Keywords:** Radiochromic film; Gafchromic EBT; Radiation dosimetry; Energy dependence; Dose response

## 1. Introduction

In medical radiotherapy, X-ray dose measurements can be performed with a variety of detectors ranging from essentially point dosimeters, like thermoluminescent crystals (Duggan et al., 2000), to films, which provide two-dimensional mapping (Suchowerska et al., 1997). The major shortcomings of the radiographic films based on silver halide are a strong X-ray energy dependence of their response to dose and the need for development. The major shortcoming of most radiochromic films was relatively low sensitivity, which required doses an order of magnitude higher than dose fractions typically delivered in radiation therapy. How-

ever, a new film, EBT Gafchromic, has been recently developed specifically for radiotherapy applications, which is almost free of all these drawbacks. Its response is relatively energy-independent, and its sensitivity is sufficient for accurate measurements of doses in the range of 0.5–5 Gy clinically used in radiation therapy. It appears to be ideal for two-dimensional measurements of X-ray doses. In this work, we have investigated the dependence of its response on the radiation energy in a broad range from superficial to megavoltage X-rays.

## 2. Materials and methods

Gafchromic EBT radiochromic film (ISP Corp., Wayne, NJ, USA) contains an active, radiation-sensitive, polymer between two protective layers of polyester, which allows the film to be easily handled and minimizes effects of ultraviolet exposure (Butson et al., 2003). The

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effective atomic number ( $Z_{\text{eff}}$ ) of the EBT film is 6.98, which is close to the corresponding value for water (7.3). In this study, the film was irradiated to 2 Gy in a  $30 \times 30 \times 30 \text{ cm}^3$  solid-water phantom (Constantinou et al., 1982) using a Pantak, Therapax 300DXT orthovoltage machine and a Varian 2100C linear accelerator. The absorbed dose calibrations were performed with a Farmer thimble-type ionization chamber according to the IAEA protocol (International Atomic Energy Agency (IAEA), 1987). The effective energy of each beam was calculated from half value layer (HVL) measurements. The spectra of the irradiated films were recorded with a Shimadzu UV-160 UV-visible spectrophotometer (Butson et al., 2002) in the range from 500 to 700 nm in 2-nm steps. This is the range of highest sensitivity of the EBT radiochromic film.

### 3. Results and discussion

Table 1 lists relative values of the response of the EBT radiochromic film to the same dose of 2 Gy over the X-ray energies tested. The responses are normalized to the response at the effective energy of 1.5 MeV achieved at 6 MVp. This energy is within the linear ranges of the energy dependences of the responses of most radiation detectors due to the high percentage of Compton interactions at this energy in most materials. Fig. 1 shows the same data in comparison with energy dependences of the responses of several other dosimetric materials (Butson et al., 2003; Cheung et al., 2004). As can be seen, the response of the EBT radiochromic film to the dose of 2 Gy depends on the X-ray energy only slightly. Its maximal variation over the range from 28 keV to 4 MeV was calculated to be 8% with an uncertainty of 4%. The dose 2 Gy is a typical dose provided in fractionated radiation treatments. For this experiment each film type requires a different delivered dose for accurate assessment. Doses delivered to each film type are, EBT Gafchromic-2 Gy. Gafchromic HS-5 Gy. Gafchromic XR type R-5 Gy. Kodak X-Omat V-20 cGy. LiF TLD's-1 Gy.

Among film-type dosimeters, the closest competitor in terms of the minimal energy dependence of the response would be Gafchromic HS film, but variations of its response are as big as 30% over in the same energy range (Butson et al., 2003). Moreover, the HS film needs significantly higher doses (5–10 Gy) for the same level of accuracy of relative dose measurements. Radiographic film exhibits the same or higher sensitivity to radiation doses as the EBT film, but, as can be seen from Fig. 1, variations of its response to the dose with energy in this range exceed one order of magnitude.

Table 1  
Responses of EBT Gafchromic film to 2 Gy at different radiation energies

Effective energy		Response, rel. units ( $\pm 0.037$ , SD)
(keV)	(kVp)	
28	50	0.923
32.5	75	0.926
39	100	0.930
53	125	0.929
68	150	0.928
94	200	0.946
119	250	0.956
1500	6000	1.000
5500	18000	0.996

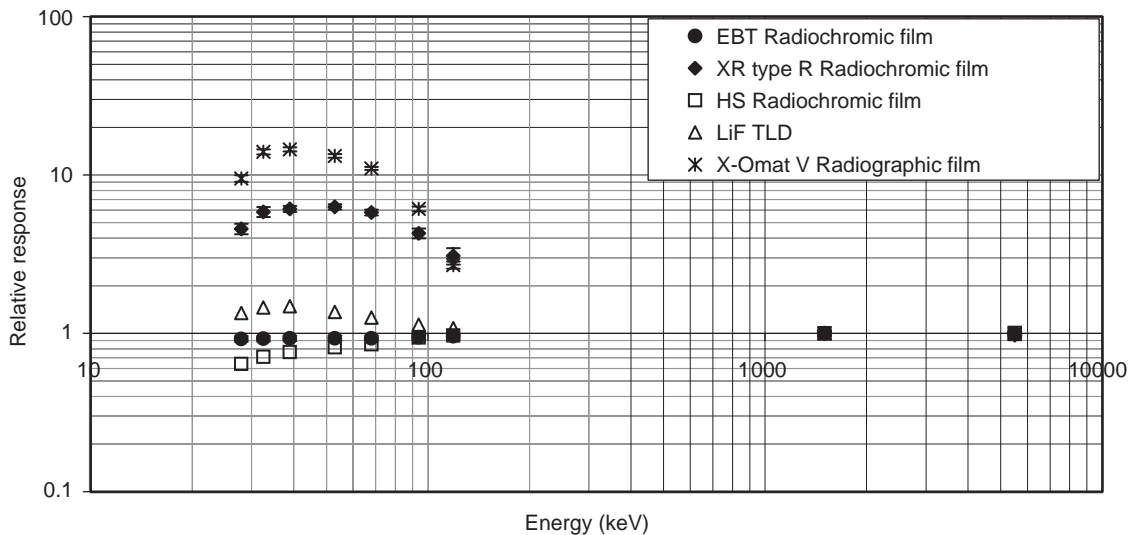


Fig. 1. Dependence of the dose responses of various types of dosimeters used in radiotherapy on photon energy.

Like radiographic film, the EBT radiochromic film can provide two-dimensional X-ray dose assessments in radiotherapy applications. However, radiographic film requires a special developing operation, which may introduce additional inaccuracies; by contrast, the EBT film develops automatically due to radiation-induced polymerization reactions within its sensitive layer. It has a very weak energy dependence of the dose response. This is ideal for radiotherapy where doses are often delivered with X-rays of a broad spectrum and this spectrum may vary with parameters of the treatment. Due to its performance characteristics, EBT radiochromic film may well constitute the next generation of films for X-ray dosimetry in clinical radiotherapy.

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