Improved method for in vivo dosimetry in pelvic intra-operative radiation therapy using *Gafchromic* films and customized digitization templates

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Purpose

In vivo measurements using *Gafchromic* EBT3® film are part of our routine quality assurance during electron intra-operative radiation therapy (IOERT) for rectal cancer[1]. The current method uses only three 1.5x1.5cm^2 pieces of film per procedure[1], but the complexity of the pelvic irradiation geometry makes it desirable to increase the number of film samples, to ensure complete coverage of the irradiated length as shown in Figure 1.

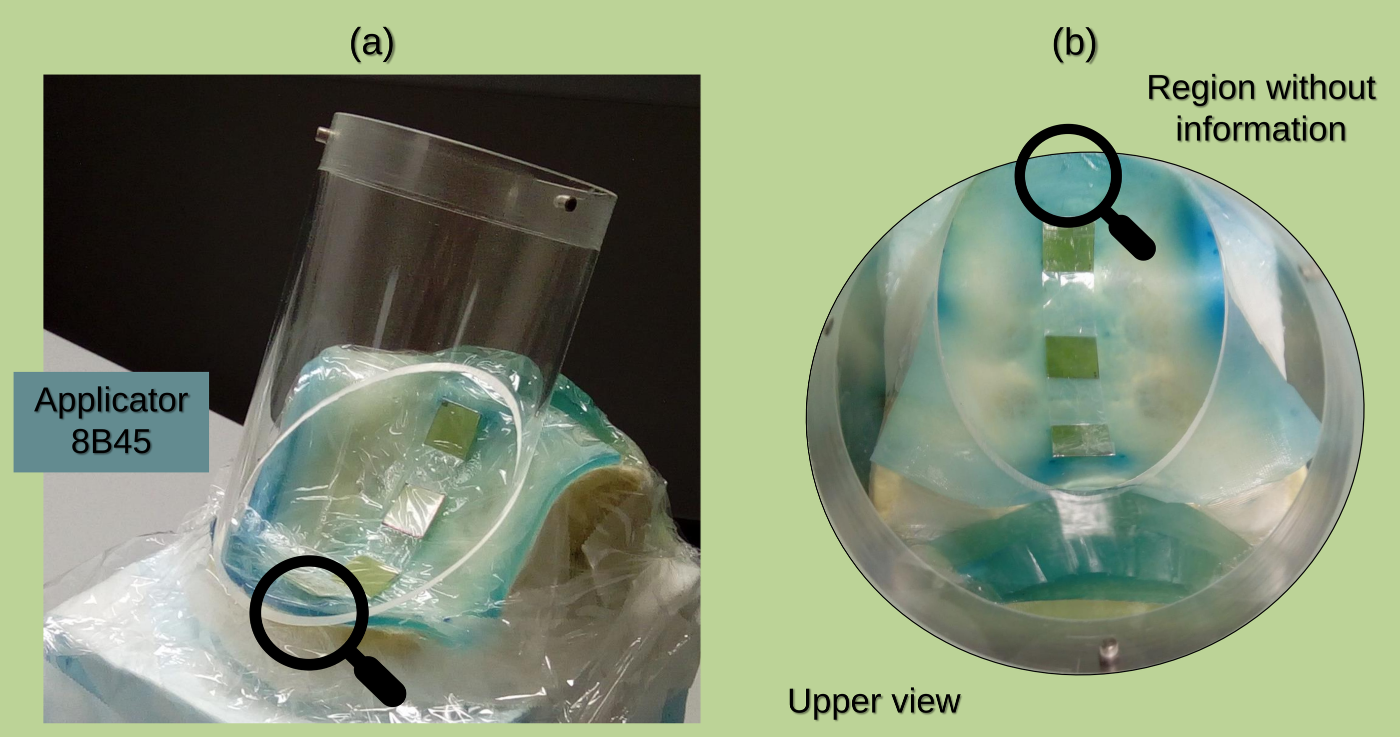

Figure 1 – Sacral bone model with 3 film pieces of *Gafchromic* EBT3 : **(a)** Applicator 8B45 position and **(b)** applicator's upper view.

The positioning of small films for digitization is time consuming and challenging. The aim of this work is to implement a practical digitization method which combines time efficiency and reduction of uncertainties.

Methods

Three sample sizes (see Figure 2) with the same width (1.5 cm) and different length (0.75, 1.0 and 1.5 cm) were evaluated. Combinations of equal-sized, equally spaced samples were tested in the sacrum model (Figure 1(a)) for typical IOERT applicators.

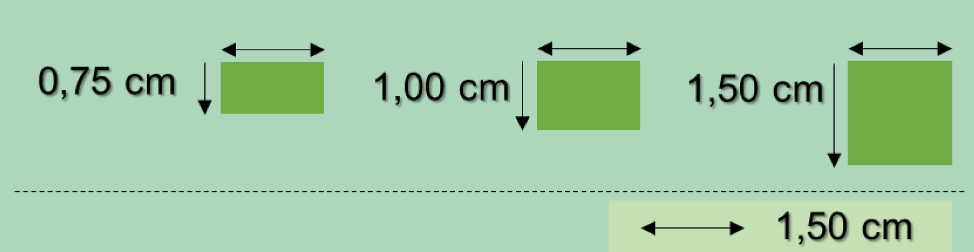

Figure 2 – Different sizes of film pieces tested.

Film samples were digitized using a flatbed scanner Epson 10000XL. The uncertainties related to the films and digitization process were quantified in a previous work. The most important reducible sources of uncertainty identified were:

(1) Variation of film-to-light source distance;

(2) Long and short term scanner fluctuations;

(3) Light-dark discontinuities between the film's edges and its surroundings, along the lateral scanning direction;

On the other hand, small rotation of films (up to 5º degrees) were found to be a negligible source of uncertainty. With these points in mind, several opaque and transparent templates for digitization were developed and tested.

Results

The cutting, handling and positioning of films smaller than 1x1.5 cm^2 were discarded as impractical. Film samples of 1x1.5 cm^2, 1 cm apart, proved the best option for adequate coverage of the irradiated length, using strips of 3 to 10 samples according to applicator size. The selected template is outlined in Figure 3.

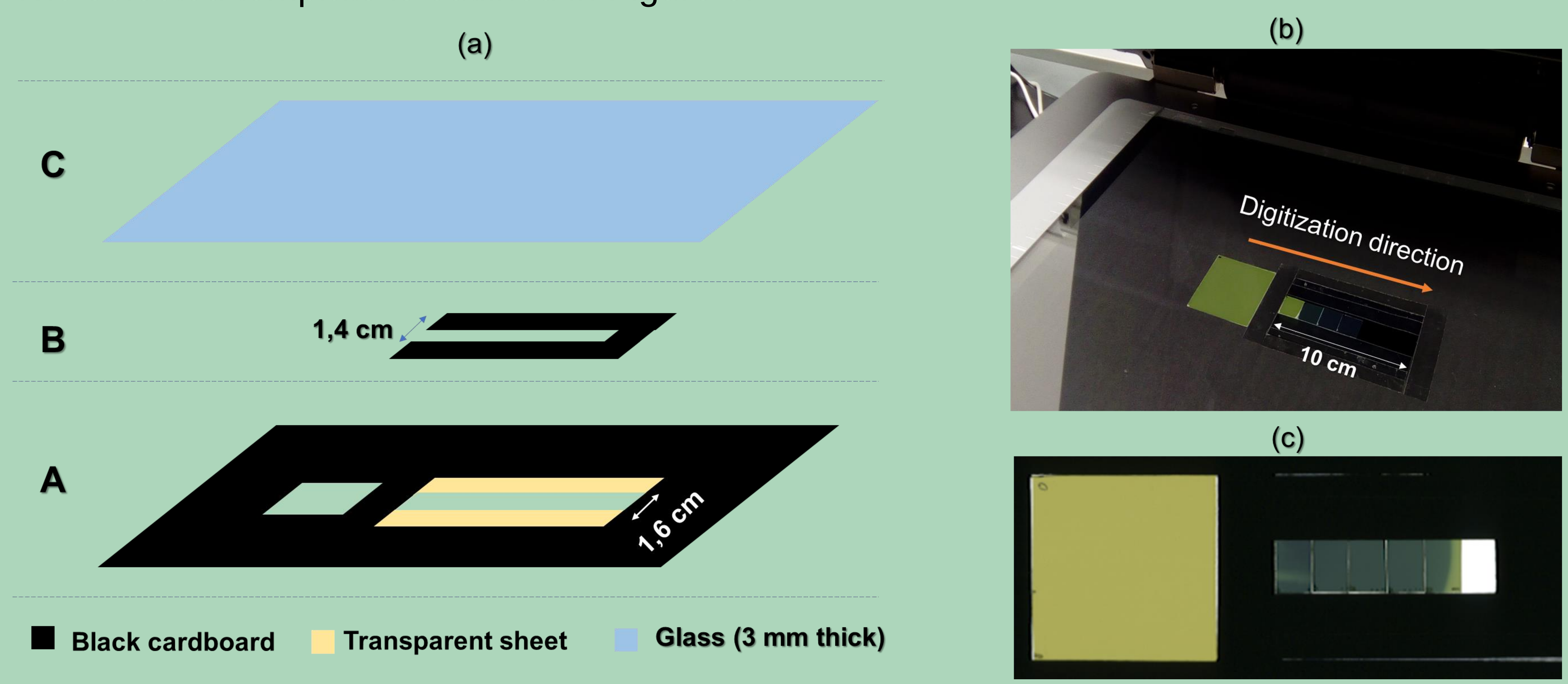

Figure 3 – (a)Template placement scheme. **A**: black cardboard with acetate to place the reference and the irradiated film's samples; **B**: cardboard piece to minimize the signal lateral discontinuity; **C**: glass with 3 mm of thickness. (b) Example of the template placement in the scanner bed . (c) Image from an IOERT treatment where 5 film's samples were used.

The relevant sources of uncertainty were addressed as follows:

(1) A uniform film-to-light source distance was achieved with a 3 mm thick glass plate covering all the scanning surface (including calibration area, so that its effect on film response will be cancelled out). The glass plate compresses and fixates the films, avoiding the need for adhesive tape, which proved impractical for such small films.

(2) The template shown in Figure 3 allows simultaneous digitization of up to ten irradiated films, avoiding short term scanner fluctuations. A reference non-irradiated film piece is included for simultaneous zero response quantification.

(3) An opaque template minimizes the light-dark discontinuities for films irradiated with 10 to 15 Gy (dose interval of interest), as the color contrast is small. However, it has the opposite effect on the reference film, as seen in the profiles presented in Figure 4 (see arrows).The use of a reference film of bigger size (5x5 cm^2) allows the selection of a central ROI where the discontinuity is not present (see Figure 4(b)).

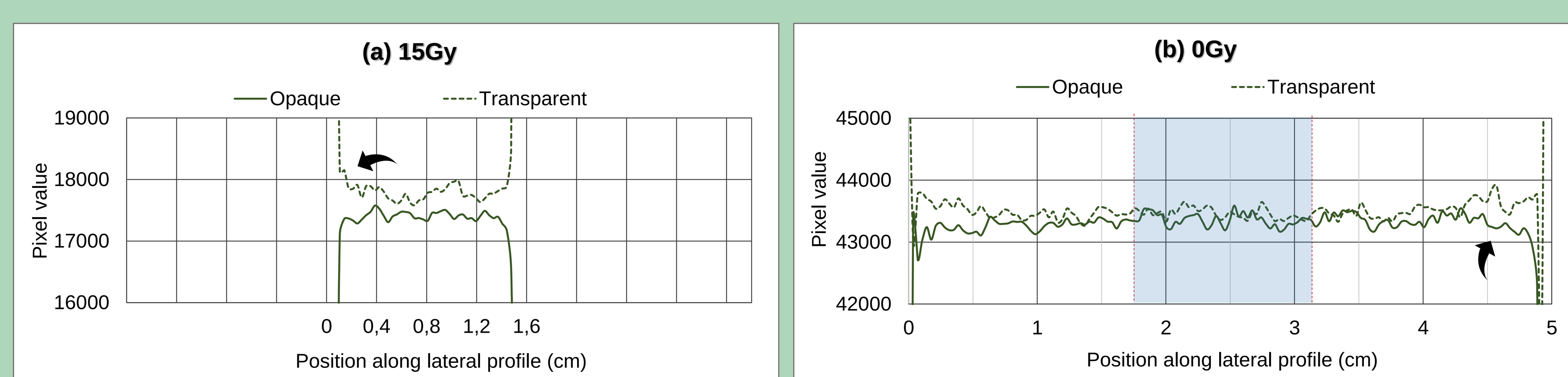

Figure 4 – Transversal profile with templates of different opacities for a film irradiated with 15Gy (a) and an unirradiated film (b).

Using this new methodology, the relevant uncertainties were reduced and the number of possible measurement points was increased from 3 to 10. Additionally, the time interval between irradiation and digitization is now constant for all the film samples.

Conclusions

In vivo measurements in IOERT were optimized by using smaller film samples and an opaque template to read up to ten films in a single scan. These changes allow a better characterization of the irradiated area with a faster and more accurate digitization method.

[1] Costa F, Sarmento S, Gomes D, Magalhães H, Arrais R, Moreira G, et al. In vivo dosimetry using Gafchromic films during pelvic intraoperative electron radiation therapy (IOERT). Br J Radiol 2016;89(1063):20160193.

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