Point dose measurements for brachytherapy with a cylinder applicator

R Rahmawati, W E Wibowo and S A Pawiro

Department of Physics, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Kampus UI Depok, Depok 16424, Indonesia

Radiotherapy Department, RSUPN Cipto Mangunkusumo, Jakarta 10430, Indonesia

Corresponding author's e-mail: supriyanto.p@sci.ui.ac.id

Abstract. Point dose measurements were conducted in High dose-rate (HDR) brachytherapy with a cylinder applicator using an EBT3 gafchromic film. The main objectives of this study were to determine the characteristics of an EBT3 film and evaluate the treatment dose of brachytherapy between manual and normalized measurements. Evaluation of the dose treatment was performed by comparing the dose values at four measurements (namely A1, A2, A3, and A4) points with the dose values after being normalized. The first two points A1 and A2 are the prescription points to the right and left of the cylinder applicator. The dose measurements at these two points were measured for three variations of distance (13, 14, and 15 mm) to the source of brachytherapy. The other two points, A3 and A4, are located at a distance of 1.5 cm above the two points, A2 and A1. The most suitable calibration for point dose measurements is the 13-mm distance, which results in the discrepancy values for points A1, A2, A3, and A4 are −0.37 %, −3.40 %, −1.39 %, and −1.54 %, respectively.

Keywords: brachytherapy, calibration, dose, EBT3 gafchromic film, point dose, TPS

1. Introduction

Cancer is one of the main causes of death worldwide [1]. Vaginal cancer is typically rare, occurring in only 2–3 % of all cases of malignancy of the female genital tract. It may be a metastasis from other gynecological cancers, and at least roughly 30 % of cases of primary vaginal cancer involve a history of previously treated cervical cancer [2].

The modality of cancer therapy is radiotherapy using ionizing radiation derived from either a linear accelerator or radioactive sources. On the basis of the distance from the radiation source to the target tumor, radiotherapy is classed as either (i) external radiotherapy using a teletherapy machine or (ii) brachytherapy using encapsulated radionuclide sources. Brachytherapy (sometimes known as curietherapy or endocurie therapy) refers to the proximal cancer treatment given by placing sources directly into or near the volume to be treated [3]. The advantages of brachytherapy over external-beam radiotherapy include (i) the dose being more localized to the target tumor and (ii) the patient not receiving a surface skin dose [4]. A previous study by Ayoobian et al. [5], which was performed using a PMMA phantom and an EBT gafchromic film dosimeter, showed measurement uncertainties of 4.1 % and 4.6 % for the calibration dose and the trial dose rate, respectively [5].

In the present study, we evaluated point doses of brachytherapy that used a cylinder applicator. For the experiment, we used an EBT3 gafchromic film dosimeter that had to be calibrated in advance to ensure that the film could function properly and could provide accurate information at each measurement.
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The acrylic phantom and measurements. stages EB T3 gafchromic film, and an EPSON Perfection V700 scanner. Overall, this study comprised three stages, namely, 1) phantom and cylinder-applicator scanning, 2) film calibration, and 3) point dose measurements.

Stage 1 was performed using the CT simulator. Phantom scanning was performed on both the acrylic phantom and the solid water phantom, which were sandwiched together as shown in figure 1. The image was then sent to the Oncentra 3D TPS software.

Stage 2 involved calibrating the EB T3 gafchromic film. The film was cut into rectangles measuring 1.5 cm × 2 cm that were placed at the measurement points as shown in figure 2. Calibration was done by varying (i) the film-to-source distance from 10 mm (surface of cylinder applicator) to 15 mm at intervals of 1 mm and (ii) the dose prescription from 500 to 1,200 cGy at intervals of 100 cGy for each film-to-source distance. After the measurements were taken using the pieces of EB T3 gafchromic film, the exposed film was scanned using the EPSON scanner with a resolution of 72 dpi and 48 bit and saved in TIFF format. The pixel value for each film was read using the ImageJ software. We use the pixel value to obtain the net optical density netOD as

\[
\text{netOD} = \log_{10}\left(\frac{PV_{\text{unexp}}}{PV_{\text{exp}}}\right)
\]

where \(PV_{\text{unexp}}\) is the pixel value of the unexposed film and \(PV_{\text{exp}}\) is the pixel value of the film having been exposed to radiation.

Stage 3 involved brachytherapy point dose measurements. These measurements comprised manual and normalization measurements with film-to-applicator distances of 3, 4, and 5 mm or film-to-source distances of 13, 14, and 15 mm, which are located at prescription points. The first and last source indices were arranged so as to obtain the same prescription dose. In these measurements, the prescription dose was set as 700 cGy. In treatment planning, the prescribed dose is merely homogeneous at the prescription point. Normalization of prescribed dose is done so that the dose becomes homogeneous automatically along the outline target using predefined dose points. We used an Iridium-192 source with a size of around 7 cm. Figure 3 shows the four measurement points at which we located the 1.5 cm × 2 cm EB T3 gafchromic films.

Figure 1. Phantom scanning using a CT simulator.

Figure 2. Schematic of film calibration: (a) front view; (b) side view.

2. Methods

All measurements were performed using a Brachytherapy mHDR Elekta Nucl etron microSelectron with an Iridium-192 source, a GE Bright Speed CT simulator, the Oncentra 3D TPS software, a cylinder applicator with a diameter of 2 cm, an acrylic phantom with dimensions 30 cm long × 30 cm wide × 3 cm thick, a solid water phantom with dimensions 30 cm long × 30 cm wide × 1 cm thick, an EB T3 gafchromic film, and an EPSON Perfection V700 scanner. Overall, this study comprised three stages, namely, 1) phantom and cylinder-applicator scanning, 2) film calibration, and 3) point dose measurements.

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Figure 3. Point dose measurement: (a) positions of the film and phantom; (b) geometry schematic.

Figure 4. Calibration curves: measurement points (a) 1 and (b) 2.

The dose evaluation was based on American Association of Physicists in Medicine Task Group Report No.119 (AAPM TG 119) to calculate the number of differences (discrepancy) relative to the measurement and planning doses in TPS with equation (2):

$$\text{Discrepancy} \, (\%) = \frac{(D_{\text{measured}} - D_{\text{planned}})}{D_{\text{planned}}} \times 100\%,$$

where $D_{\text{measured}}$ is the measurement dose and $D_{\text{planned}}$ is the planned treatment dose.

3. Results and discussion

Figure 4 shows the relationship between the source-to-film distance and netOD. Films farther from the source have netOD values that tend to be greater for each dose value. However, at distances exceeding 14 mm, netOD decreases with distance. The maximum netOD value is at a distance of 14 mm from the source, indicating that electronic equilibrium occurred at a distance of 14 mm.

We measured the dose at four points labeled A1, A2, A3, and A4. At A1 and A2, the film was located to the right and left of the applicator cylinder, respectively, at the same depth in the acrylic slab phantom. Points A3 and A4 were located 1.5 cm above A1 and A2 as illustrated in figure 3. The netOD values were obtained using equation (1), and the pixel values were obtained using the ImageJ software after the films were processed.

Comparing the manual and normalization (automated) discrepancy graphs for A1 and A2 for various source distances, as shown in figure 5a and figure 5b, we see a similar discrepancy pattern. This occurs because the measurement points for the films at A1 and A2 are at the same depth in the solid water phantom. In these figures, A1 and A2 are to the right and left of the cylinder applicator, respectively, causing the distance that affects the dose calculations to be roughly the same for both points.

The results shown in figure 5c and 5d for measurement points A3 and A4 show almost the same discrepancy patterns because the two points are at the same depth. However, the discrepancy patterns for A1 and A2 differ from those for A3 and A4. These differences may be due to the differences in
Figure 5. Discrepancy of manual and normalization measurements for (a) A1, (b) A2, (c) A3, and (d) A4 points

film depth upon exposure, which means that the distance between the measurement points is also different, resulting in differences in measured dose and the resulting discrepancy pattern.

From the graphs shown in figure 5, we can conclude that the discrepancy when using the 14-mm calibration always generates negative values of the point dose discrepancy. This indicates that the measured dose with the 14-mm calibration is always lower than the TPS-calculated dose. The most suitable calibration for point dose measurements is the 13-mm calibration, with which the discrepancy values for A1, A2, A3, and A4 were −0.37 %, −3.40 %, −1.39 %, and −1.54 %, respectively. The discrepancy obtained for 13-mm calibration are within the range values obtained by Ayoobian et al. [5], who conducted research using a PMMA phantom and an EBT gafchromic film dosimeter. The results obtained in this study indicate that the uncertainty in the calibrated dose measurement is 4.1 %.

4. Conclusions
On the basis of the results of the present study, we can draw some conclusions that the measurements in this study produced both positive and negative discrepancy values. A positive discrepancy means that the measured result exceeds the TPS-calculated dose, whereas a negative discrepancy means that the measured result is smaller than the TPS-calculated dose. Also, the most suitable calibration for point dose measurements is the 13-mm calibration, for which the discrepancy values for points A1, A2, A3, and A4 were -0.37 %, -3.40 %, -1.39 %, and -1.54 %, respectively.

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