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The Detector Characteristics for Output Factor Measurement of Small Field Electron Beams

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Abstract. Have been performed the output factor measurements of the small square field with dimensions of 8 x 8 cm^2 and smaller, for electron beams with energy of 6, 8, 10, 12, and 15 MeV. The experiments has been performed using the Elekta Synergy Platform Linac, solid water, the Exradin A11 plan-parallel ion chamber, Exradin A16 micro ion chamber, PTW Freiburg T60010M-4 silicon diode, and Gafchromic® EBT-3 film. The result described that the output factor of all detectors decreased with decreasing field size and energy electron beams. The comparison of output factor to output at reference condition for all detectors has discrepancy maximum in the range of 49.5-87.6 % on field 1 x 1 cm^2 for 6 MeV, and a minimum value in the range of of 0.49-1.21 % on 8 x 8 cm^2 for 15 MeV so it makes the dose distribution of electron treatment of square field of 1 x 1 cm^2 were not appropriate for patient treatment. In this study, PTW Freiburg T60010M-4 silicon diode and Gafchromic® EBT-3 film demonstrated more compatible for small field electron beam measurement.

Keywords: small field, output factor, electron beam dosimetry

INTRODUCTION

The electron beam has been used in clinical cancer therapy for superficial lesions because it has a uniform dose distribution at the surface of phantom or patient [1]. Cancers surrounding organs at risk, such as an eye, ears, nose, and lips must require special attention. Some authors proposed using small field electron beams to treat the cancer with those conditions. Beside small field radiotherapy require accurate dosimetry, we need to pay attention to small directionality error margins, possibly a nonstandard treatment distance, and a small treatment field [2, 3]. However, electron beams of dose distribution is hard to predict and become a challenge because of the complexity of the beam energy and complicated trajectory of particles by collimating elements such as patient body, scattering foils, and electron inserts or applicator [4].

For dosimetry, international protocols such as AAPM TG-25 and IAEA TRS-398 are usually used to measure output factor electron beam radiotherapy. However, small field electron beams is not standard condition with different geometry and field size as indicated in standard protocols. The detectors with angular and energy dependence, for example diamond detectors or silicon diodes, are more preferable to use in small beam geometries measurement. Some types of detectors such as ionization chambers, diodes, TLDs, film dosimetry, and a plastic scintillator have been used to measure output factor for small electron fields [5]. In this study, we exercised the output factor of small field electron beam using Exradin A11 plan-parallel ionchamber, Exradin A16 micro ion chamber, PTW Freiburg T60010M-4 silicon diode, and Gafchromic® EBT-3 film.

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MATERIALS AND METHODS

This study was conducted using the Linac Elekta Synergy Platform beam that produces photon beams with 6 and 10 MV and an electron beams with energies of 6, 8, 10, 12, 15, and 18 MeV. We employed the electron applicator 6 x 6 cm^2 and 10 x 10 cm^2 and various square field sizes of 1 x 1 cm^2, 2 x 2 cm^2, 3 x 3 cm^2, 5 x 5 cm^2, 8 x 8 cm^2, and 10 x 10 cm^2. Output measurement was performed using the Exradin A11 plan-parallel ion chamber, Exradin A16 micro ion chamber, PTW Freiburg T60010M-4 silicon diode, and Gafchromic® EBT-3 film. All detectors were employed and took placed on slab solid water phantom at depth dose maximum (z_{max}) with SSD 100 cm. For measurements, electrometer Max 4000 was connected to the detector Exradin A11 plan-parallel ion chamber and Exradin A16 micro ion chamber. Furthermore, electrometer PTW Vivodos was used to read the signal from PTW Freiburg T60010M-4 silicon diode, while Gafchromic® EBT-3 film has employed a flat-bed scanner Epson Perfection V700 to calculate the pixel value of the film. We used the arrangement of Kesen *et al*. [3] in determining and measuring output at the reference condition and maximum depth ($z_{\max}$). In order to determine the output factor, we calculated and compared the measurements at depth dose maximum (z_{max}) for a various detector, field sizes and energy to the measurements at the reference condition of 10 x 10 cm^2.

RESULTS AND DISCUSSION

The measurement output factors small field electron beam for various energy and detectors are shown in Fig. 1. Figure 1 shows that the output factor of PTW Freiburg T60010M-4 silicon diode and Gafchromic® EBT-3 film curve tends to overlap from field size of 10 x 10 cm^2 to 2 x 2 cm^2. It also describes that the output factor of PTW Freiburg T60010M-4 silicon diode and Gafchromic® EBT-3 filmis slightly higher compared to Exradin A11 plan-parallel ion chamber and Exradin A16 micro ion chamber. Furthermore, the output factor of Exradin A11 plan-parallelion chamber is the lowest value compared to the other detectors. The output factor of the four detectors have a minimum value between 0.12-0.50 at field size of 1 x 1 cm^2 for 6 MeV, and a maximum value between 0.98-0.99 on 8 x 8 cm^2 for 15 MeV. Additionally, the output factor of PTW Freiburg T60010M-4 silicon diode is decreasing up to 0.50 at field size of 1 x 1 cm^2 for 6 MeV where as the output factor at field size of 8 x 8 cm^2 for 15 MeV is close to reference output factor with differences around of 0.49 %. The output factor of Gafchromic® EBT-3 film is similar to the measurement of PTW Freiburg T60010M-4 silicon diode. In addition, the output factor of Exradin A16 micro ion chamber is around of 0.40 at field size of 1 x 1 cm^2 for 6 MeV where as the output factor of Exradin A11 plan-parallel ion chamber is the lowest value compared to other detectors at about 0.12. On the other hand, the output factor of two extradin detectors at 8 x 8 cm^2 for 15 MeV is closed to the output factor of other detectors.

Figure 1a, b1, and 1c show that the differences of ouput factor between PTW Freiburg T60010M-4 silicon diode and Exradin A16 micro ion chamber at field size of 3 x 3 cm^2 are around of 7 % for 6, 8, and 10 MeV, where as the discrepancy of output factor at field size of 3 x 3 cm^2 between the PTW Freiburg T60010M-4 silicon diode and Exradin A16 micro ion chamber tend decrease with increasing energy electron beams. On the other hand, the discrepancy of output factor between PTW Freiburg T60010M-4 silicon diode and Exradin A11 plan-parallel lion chamber at field size of 3 x 3 cm^2 has maximum value around of 25 % at 6 MeV and minimum value around of 5 % at 15 MeV.

For field size 2 x 2 cm^2 in PTW Freiburg T60010M-4 silicon diode, we found that the minimum output factor value is at about 0.89 for 6 MeV and maximum value around of 0.96 for 15 MeV. On the one hand, the output factor of Gafchromic® EBT-3 film is also close to output factor of PTW Freiburg T60010M-4 silicon diode. While the discrepancy of output factor between PTW Freiburg T60010M-4 silicon diode and Exradin A11 plan-parallel ion chamber at filed size of 2 x 2 cm^2 has maximum value around of 47 % at 6 MeV and minimum value around of 22.5 % of 15 MeV, the discrepancy of output factor between PTW Freiburg T60010M-4 silicon diode and Exradin A16 micro ion chamber at field size 2 x 2 cm^2 has maximum value at about 18.4 % for 6 MeV and minimum value around of 4.8 % for 15 MeV. Generally, the output factor for all detectors at field size 2 x 2 cm^2 are tend decrease with increasing energy electron beams.

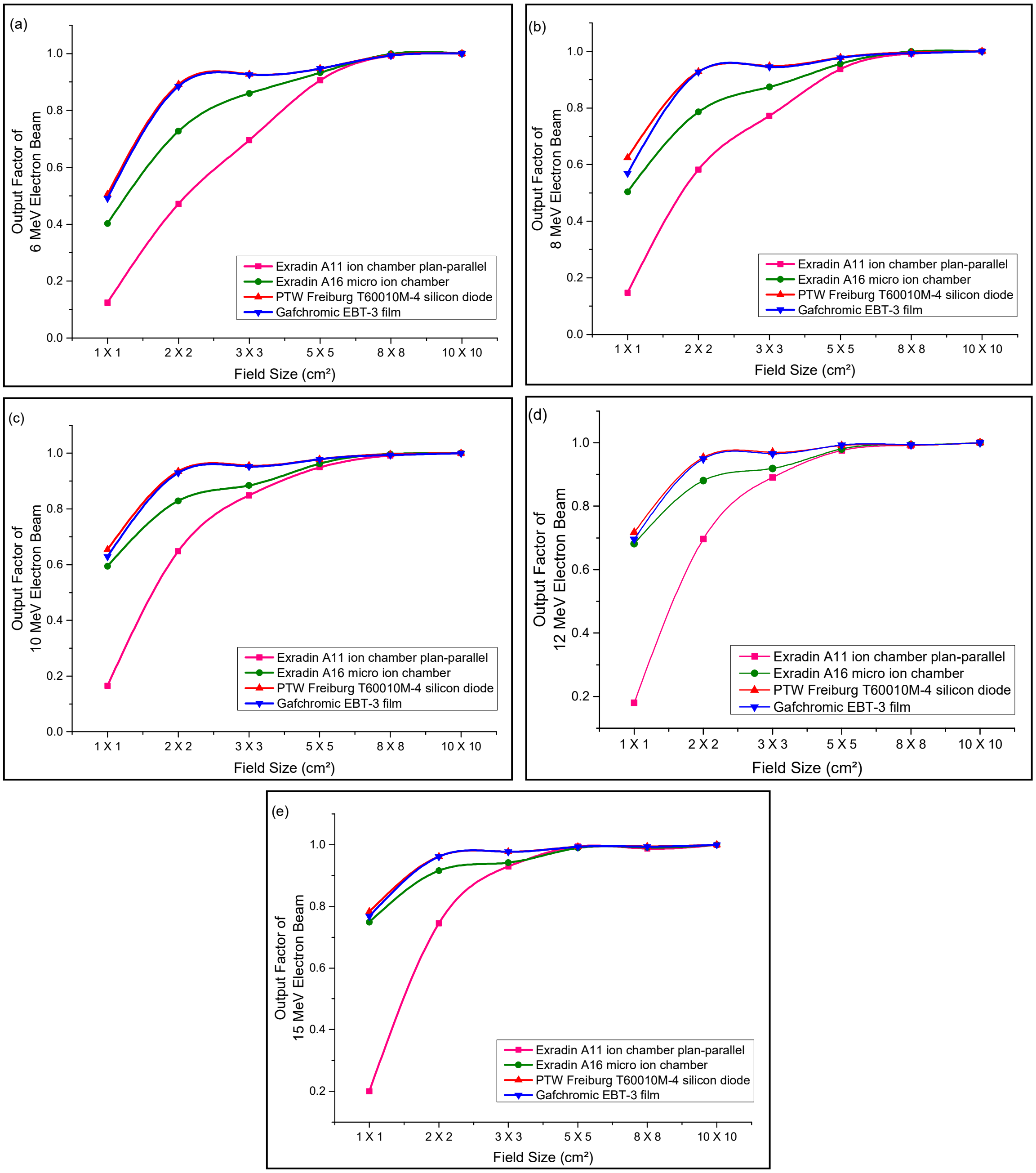

FIGURE 1. Comparison of Output factor in small field using Exradin A11 plan-parallel ion chamber, Exradin A16 micro ion chamber, PTW Freiburg T60010M-4 silicon diode, and Gafchromic® EBT-3 film

For field size 1 x 1 cm^2 in Exradin A11 plan-parallel ion chamber we found that the minimum output factor value is at about 0.12 for 6 MeV and maximum value around of 0.20 for 15 MeV. The ouput factor are extremely different between PTW Freiburg T60010M-4 silicon diode and Exradin A11 plan-parallel ion chamber shown at Fig. 1a, 1b, 1c, 1d, and 1e. The discrepancy of output factor between PTW Freiburg T60010M-4 silicon diode and Exradin A11 plan-parallel ion chamber is around of 75 % for all energy electron beams. Furthermore, the discrepancy at field side of 1 x 1 cm^2 between PTW Freiburg T60010M-4 silicon diode and Exradin A16 micro ion chamber has maximum value at about 20.3 % for 6 MeV and minimum value around of 4.3 % for 15 MeV electron beam.

Generally, the output factor for all detectors decreased with decreasing of field size and energy electron beam, nor vice versa. Small cutouts affected electron beam side deflections predominated by multiple Coulomb scattering. The lack of electron lateral - scatter equilibrium gave the reduction of output factor for all detectors, so the dose distribution of electron treatment for small field of 1 x 1 cm^2 were not appropriate for patient treatment [6,7].

The lack of electron lateral - scatter equilibrium can occur even worse when the detector is used larger than the irradiation field size. This can happen due to the volume averaging effect at each detector. If the beam field size smaller than the active area of the detector, that would measure in the center of the area of the large detector, so dose underestimation when measuring output factors in small fields [8]. When we compared the size of the detector, the detector Exradin A11 plan-parallel ion chamber, Exradin A16 micro ion chamber has an active volume 0.62 cm^3 and 0.007 cm^3, whereas PTW Freiburg T60010M-4 silicon diode has an active density of 2.0 g/cm^2, and Gafchromic® EBT-3 film has very small grain of film. This condition support the statement that the PTW Freiburg T60010M-4 silicon diode and Gafchromic® EBT-3 film have a stable output factor without the influence of lack of electron lateral - scatter equilibrium, unaffected by the volume averaging effects. Therefore, it can be stated that the silicon diode PTW Freiburg T60010M-4 and Gafchromic® EBT-3 film are more compatible for small field electron beam measurement [3-5].

CONCLUSIONS

The output factor of all detectors decreased with decreasing field size and energy electron beams. The comparison of output factor to output at reference condition for all detectors has discrepancy maximum in the range of 49.5-87.6 % on field 1 x 1 cm^2 for 6 MeV, and a minimum value in the range of of 0.49-1.21 % on 8 x 8 cm^2 for 15 MeV so it makes the dose distribution of electron treatment of square field of 1 x 1 cm^2 were not appropriate for patient treatment. In this study, PTW Freiburg T60010M-4 silicon diode and Gafchromic® EBT-3 film demonstrated more compatible for small field electron beam measurement.

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