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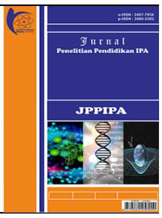

Measuring and Determining the Output Factor of 6 and 10 MV WFF Photon Beams in Small Square and Rectangular Fields using Semiflex TM 31010 and Pinpoint TM 31014 Ionization Chamber

Margaretha Berek[1]*, Johan Andoyo Effendi Noor[2], Unggul Pundjung Juswono[2], Fatimah Kunti Hentihu[3], Alfian Khoiri Anto[3], Sigma Nur Rismawati[1], Ayu Hardianti Pratiwi[1], Karimah[1]

[1] Master of Physics Study Program, Brawijaya University, Malang, Indonesia
[2] Departement of physics, Brawijaya University, Malang, Indonesia
[3] Departement of Radiotherapy, Lavalette Hospital, Malang, Indonesia

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Corresponding Author:
Margaretha Berek
ethaberek18@gmail.com

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Abstract: Research has been carried out on Measuring and Determining the Output Factors of 6 and 10 MV WFF photon beams in Small Square and Rectangular fields using Semiflex TM 31010 and PinPoint TM 31014 Ionization Chamber. This study aims to determine the value of the small field output factor. Measurements were carried out in a water phantom at a depth of 10 cm with a 100 cm SSD technique. The area of the irradiation field used is (2 × 2; 3 × 3; 4 × 4; 2.5 × 1.6; 3.6 × 2.5; 4.5 × 2; and 5 × 3.2) cm^2. Field output factor calculations were performed using the IAEA TRS. 483 dosimetry protocol. The results of measurements and calculations obtained for the two detectors used show that a decrease in the value of the output factor occurs when the field size is getting smaller. The output factor value in a small rectangular field looks smaller when compared to the output factor value in a small square field.

Keywords: Output Factor; Small field; Square field; Rectangular field

Introduction

Linac is a radiotherapy instrument that can emit photon beams with radiation qualities that vary from low energy to high energy precisely on target (Firmansyah et al., 2017). With adequate technological developments, currently, Linac can be used for radiation therapy using several radiotherapy techniques, namely: *Intensity Modulation Therapy* (IMRT), *Intensity Guided Radiation Therapy* (IGRT), and *Stereotactic Radiotherapy* (SRT)/*Stereotactic Radiosurgery* (SRS). The three radiotherapy techniques can make it easier to treat small tumors with bundle shapes that can resemble the shape of the tumor (IAEA, 2017). With the use of these three radiotherapy techniques, in operating Linac to treat tumors, the use of radiation doses is expected not to exceed or less than the target dose needed to kill tumors so good and accurate treatment planning is needed. Treatment planning can be done at the TPS (treatment planning system) by entering the data needed in calculating the dose value. One of the data needed in calculating the dose is the output factor measurement data. In conventional medicine, the output factor (OF) is the ratio of the output of the Linac aircraft at a certain measurement field to the output of the Linac aircraft in a standard field area of 10 × 10 cm^2. However, in a small field area, there are differences in the calculation of the output factor value. So, it is necessary to measure the output factor in a small field.

A small field is a field that has dimensions that are smaller than the distance that can be reached by charged particles in the lateral direction, which causes a dose

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change at the measurement point along the central axis (IAEA, 2010). Where small fields generally have a size smaller than 5 × 5 cm^2 (Das *et al*, 2016). In small fields, there are several obstacles in the measurement process, namely: loss of equilibrium of charged particles in the lateral direction, occlusion of the main photon source by collimation devices, and detector sizes that are greater than or greater than the irradiation field area (Bagheri et al., 2017; IAEA, 2017). Constraints in measuring the output factor in a small field can cause weakness in the measurement results and also the calculation results, which will also cause an error in calculating the dose value at the TPS (Fatimah et al., 2016).

One of the cases that showed the existence of important problems related to absorbed dose in small fields occurred in the early 2000s. In February 2010, a hospital in Missouri announced that half of the patients undergoing stereotactic radiation therapy treatment at that hospital had an overdose of approximately 50%, which was caused by commissioning errors(Bogdanich & Ruiz, 2010). Research conducted by (Firmansyah, 2018) showed that there was a deviation of more than 2.5% in the measurement and calculation of the photon beam absorption dose rate using the TRS 398 dosimetry protocol for small-volume detectors. Božidar (2019) from the results of his research on two Linac variants (Versa HD and TruBeam) concluded that there was a decrease in the field output factor with a decrease in the size of the irradiation field which would affect the results of dose calculations at TPS, so field output factor measurements need to be carried out in small fields to increase the accuracy of dose calculations at TPS (Fatimah et al., 2016). This indicates that the use of dosimetry protocols including output factor measurement protocols for small fields is not the same as conventional fields. Therefore, it is necessary to measure and calculate the small field output factors using good and correct procedures, namely using TRS. 483 published by the IAEA in 2017.

Talking about the output factor, the IAEA (2017) defines the output factor on a small field as a result of comparing the output of the Linac aircraft on a certain field area with the output of the Linac aircraft on the standard field multiplied by the field output correction factor. The output of the Linac aircraft here is the measurement of the radiation produced per unit of time, the level of exposure in the air, the dose rate in the water, and the energy fluency level. In conditions of a small field area, the output factor becomes important in calculating the dose value for TPS. In relation to the small field, there are variations in the small field, namely a square field and a rectangular field. The radiation field represents the shape and size of the tumor to be treated, where the shape of the tumor can be square or rectangular. With different tumor shapes, this research will analyze the comparison of the output factor values of square and rectangular small fields. The results of the analysis will be used as reference data that can be considered in planning further tumor treatment.

Method

Field output factor measurements were carried out at Lavalette Hospital, Malang City with the radiation source used, namely 6 MV WFF and 10 MV WFF photon beams produced by the medical linear accelerator (Linac) *Elekta Synergy Platform*. Measurement of the field output factor used two PTW Freiburg ionization detectors, namely (Semiflex) type TM 31010 (IC), and (PinPoint) type TM 31014 (IC) coupled with a TANDEM electrometer. The phantom used is an MP3-M water phantom with a distance setting of the radiation source to the phantom surface, which is 100 cm. The Semiflex ionization detector was placed in a water phantom at a depth of 10 cm and irradiation was carried out with variations in the size of the square field, namely (2 × 2) cm$_2$, (3 × 3) cm$_2$, and (4 × 4) cm$_2$. While the variations in the size of the rectangular field which are equivalent to the area of the square field are (2.5 × 1.6) cm$_2$, (3.6 × 2.5) cm$_2$, (4.5 × 2) cm$_2$and (5 × 3.2) cm$_2$(IAEA, 2017). The same settings are also made for measurements using the PinPoint ionization detector. Furthermore, the process of calculating the output factor of a small square field and a small rectangular field using Equation 1 (IAEA, 2017).

$$\Omega^{f_{clin},f_{ref}}_{Q_{clin},Q_{ref}} = \frac{D^{f_{clin}}_{w,Q_{clin}}}{D^{f_{ref}}_{w,Q_{ref}}} = \frac{M^{f_{clin}}_{Q_{clin}}}{M^{f_{ref}}_{Q_{ref}}}\, k^{f_{clin},f_{ref}}_{Q_{clin},Q_{ref}} \tag{1}$$

Where:

$\Omega^{f_{clin},f_{ref}}_{Q_{clin},Q_{ref}}$: Field output factor of a clinical, non-reference field f_{clin} with respect to the conventional 10 cm × 10 cm reference field f_{ref}

$M^{f_{clin}}_{Q_{clin}}$: Readings of the detector (corrected for influence quantities, pressure, temperature, incomplete charge collection, and polarity effects) on small square and rectangular fields

$M^{f_{ref}}_{Q_{ref}}$: Readings of the detector (corrected for influence quantities, pressure, temperature, incomplete charge collection, and polarity effects) at reference conditions

$k^{f_{clin},f_{ref}}_{Q_{clin},Q_{ref}}$: Output correction factor of the detector used

Result and Discussion

Output Factors of 6 and 10 MV WFF Photon Beams

The results of measurements and calculations of photon beam field output factors 6 MV and the 10 MV WFFs for the Semiflex TM 31010 and PinPoint TM 31014 ionization detectors are shown in Figures 1, Figure 2, and Table 1.

Table 1. Field output factors for ionization detectors (Semiflex 0.125 cm^3 and PinPoint 0.015 cm^3) in an MP3-M water phantom.

Field size	Semiflex 0.125 cm^3		PinPoint 0.015 cm^3	
(cm^2)	10 MV	6 MV	10 MV	6 MV
2 × 2	0.8073	0.8032	0.8170	0.8069
3 × 3	0.8671	0.8452	0.8618	0.8439
4 × 4	0.9014	0.8776	0.9006	0.8779
2.5 × 1.6	0.7975	0.7886	0.8043	0.7957
4.5 × 2	0.8465	0.8298	0.8503	0.8329
3.6 × 2.5	0.8637	0.8405	0.8658	0.8422
5 × 3.2	0.8976	0.8723	0.8966	0.8717

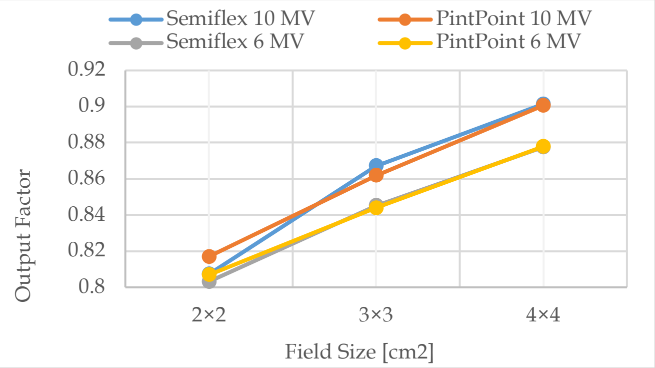

Figure 1. The photon beam field output factors are 6 MV and 10 MV WFF for a small square field size.

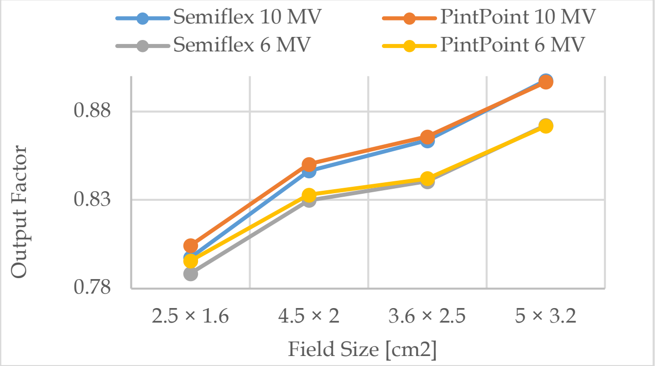

Figure 2. The photon beam field output factors are 6 MV and 10 MV WFF for a small rectangular field size.

Note: For a rectangular field area of 2.5 × 1.6 cm^2 is equivalent to a square field size of 2 × 2 cm^2; the area of a rectangular field of 3.6 × 2.5 cm^2 is equivalent to the size of a square field 3 × 3 cm^2; the area of a rectangular field of 4.5 × 2 cm^2 is equivalent to the size of a square field of 3 × 3 cm^2, and the area of a rectangular field of 5 × 3.2 cm^2 is equivalent to the size of a square field of 4 × 4 cm^2.

The field output factor is obtained by comparing the detector readings on a small field measurement with the detector readings on a standard field measurement of 10 × 10 cm_2. The detector reading values in each state are pre-corrected for influences such as pressure, temperature, incomplete charge collection, and polarity effects. To avoid larger measurement errors, measurements were carried out using two ionization detectors (Andreo, 2018; IAEA, 2017; Parwaie et al., 2018).

The results of the calculation of the small field output factor of 6 MV and 10 MV WFF photons for both detectors, both a square field and a rectangular field which are equivalent to a square field based on Figures 1, Figure 2, and Table 1, it can be seen that the value of the field output factor decreases if the area the field is getting smaller. The same results were also shown by (Božidar, 2019; Casar et al., 2019; Godson et al., 2016; Hug et al., 2018; Nasir et al., 2017; Setilo et al., 2019) the decrease in the value of the field output factor was caused by the loss of equilibrium of the laterally charged particles and the size of the detector that is larger than the size of the photon beam used. The condition of a larger detector size is indicated by the average effect of the detector's sensitive volume. While the size of the photon beam is represented by the field area, where the smaller the field size, the scattering of photons coming out of the collimator device is not replaced by scattering that enters or is received by the detector. So that charged particles in the lateral direction will lose their equilibrium as described by (Andreo, 2018; Božidar, 2019; Das et al., 2018; IAEA, 2017; Lauba & Wong, 2003). The size of the detector that is larger than the size of the outgoing photon beam will cause all sensitive parts of the detector to not be illuminated by the photon beam. This will cause a decrease in the value of the detector reading. Where the detector reading value directly affects the results of the calculation of the output factor.

Table 1 also shows the difference in the value of the output factor between the two detectors used. Comparisons were made on the Semiflex TM 31010 and PinPoint TM 31014 ionization detectors by looking at the difference in the field output factor values between the two detectors in the same photon beam. The difference in the output factor values for both the 6 MV photon beam and the 10 MV WFF photon beam between the two detectors with an average difference of 0.00412 and 0.0024 respectively. The output factor value for the Semiflex TM 31010 ionization detector is smaller if compared to the output factor value for the PinPoint TM 31014 ionization detector. This is due to the sensitive volume of the Semiflex ionization detector, which is 0.125 cm_3, which is larger than the sensitive volume of the PinPoint TM 31014 ionization detector, which is 0.015 cm_3. The detector volume which is larger than the Semiflex ionization detector causes the volume averaging effect to play an important role in decreasing the output factor value. Between the two detectors, the field output factor value for the detector (Godson et al., 2016; IAEA, 2017)

In this study, the small field is classified into two, namely a small square field and a small rectangular field. By distinguishing the two forms of small fields, in this study will be seen the difference in the results of the calculation of the output factor between the two forms of the field with the same area size. With the difference in the shape of the field, the type of detector, and also the photon beam used, there is no comparison of the value of the field output factor between the detectors or between the photon energy quantities.

Based on Table 1. there is a non-significant difference between the output factor values for small square and rectangular fields. For the 6 MV and 10 MV photon beams using the Semiflex ionization detector, the average difference between the rectangular field and the rectangular field, respectively, is 0.0101 and 0.0096. As for the 6 MV and 10 MV photon beams using the PinPoint ionization detector, the average difference between the small rectangular field and the small rectangular field, respectively, is 0.0079 and 0.0084. The difference is indicated by the output factor value in the rectangular field being smaller than the factor value. Output on a small square field. This is caused by the size of the small rectangular field in the lateral direction being smaller than the size of the square field in the lateral direction. So that the reading results will decrease and cause the calculation of the output factor for a small rectangular field to be smaller. A calculation analysis that is similar to the results of this study is shown by Nabila, Milvita and Mursiyatum, namely the results of detector readings for the same field area but different length and width measurements will also have differences. If the length and width measurements of the field sizes are exchanged, differences in detector reading values are still found based on research results (Nabilla et al., 2020).

The comparison of output factor values between the same field areas is not only compared between square and rectangular fields, but also between rectangular and rectangular fields. That is, between a field area of 3.6 cm × 2.5 cm, the output factor value looks larger than a field area of 4.5 cm × 2 cm for all photon beams. These results as explained that the difference in field size in the *lateral* can cause the signal generated at a small size not as big as the signal generated by the detector at a larger size. The difference in the value of the output factor that occurs both between detectors for the same photon beam and between the field forms for the detector and the same photon beam, although not significant, is very important to note the difference or difference in the value of the output factor. This is because it will greatly impact the input to the TPS for the treatment planning process. As explained by (Andreo, 2018), because there is no ideal detector for measuring small field output factors, the use of two or more detectors will be considered where the output factor results from both detectors can be averaged and used as reference data for the treatment planning process (IAEA, 2017).

Conclusion

The value of the field output factor is very important in the process of planning tumor treatment. So that the measurement and calculation of the output factor are done carefully. In field output factor measurement, no detector is truly ideal in measurement. So, the most recommended approach is to measure the field output factor using a different type of detector in order to reduce errors that may occur. The field output factor value for the Semiflex TM 31010 and PinPoint TM 31014 ionization detectors decreased when the field size or area was getting smaller. In the form of a small rectangular field, the value of the output factor is smaller than the value of the output factor of the field in the form of a small square field.

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