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Penumbra and Output Factors Measurements in Small and Non-Small Fields

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Abstract

Recent developed technologies in radiotherapy such as intraoperative electron therapy, stereotactic radio surgery (SRS), Intensity Modulated Radiation Therapy (IMRT), Volumetric Modulated Arc Therapy (VMAT) and conformal three-dimensional therapy provided the linear accelerator an accurate and automatic collimation of the beams such as computerized multi-leaf collimators (MLC), miniature multi-leaf collimators and tomotherapy devices which can help to deliver the dose to a patient by small fields. Zhianawa Cancer Center for radiotherapy in Iraq deals with both the new treatment technics IMRT and VMAT. It's very important to know how deal with the new techniques especially in small field dosimetry and what are the factors that effect on it. The aim of the study was to measure the penumbra and output factors by different chambers in small and non-small fields using two photon energies.

The penumbra was measured by the Pinpoint, Roos, Farmer and Semi flex chambers at 10 cm depth, using 6MV and 10 MV photon beam energy for a small fields and non-small fields defined by a conventional MLC and the output factors obtained with the four detectors for different field sizes using the same photon energies. The results showed that penumbra widths for different chambers are different, Roos chamber lesser extended than the other chambers and pinpoint chamber slightly broaden. For both energies, in the non-small field sizes the output factors for the chambers almost have the same values, but in the smaller fields they have different values and this variation increase with decreasing field sizes. We concluded that the size of the chamber has a huge effect on the output factor and penumbra of the beams and the Pinpoint chamber is an excellent choice between the chambers in our center as a detector for output measurements in IMRT.

Keywords: Small field; Penumbra; Output factors; Ionization chambers; Radiotherapy; Energy

Abbreviations: SRS: Stereotactic Radio Surgery; IMRT: Intensity Modulated Radiation Therapy; VMAT: Volumetric Modulated Arc Therapy; MLC: Multi-Leaf Collimators; IORT: Intraoperative Electron Therapy; QA: Quality Assurance; SDD: Source–Detector Distance; SSD: Source-to-Surface Distance

Introduction

The use of radiotherapy linear accelerators in special procedures such as intraoperative electron therapy (IORT), stereotactic radio surgery (SRS), intensity modulated radiation therapy (IMRT), volumetric modulated arc therapy (VMAT) and three-dimensional conformal radiation therapy (3D CRT) require additional and even more strict Quality Assurance (QA) procedures to ensure the level of confidence in the accuracy of dose delivered. Also the planning and delivery phases of radiotherapy treatment are the responsibility of specially well-trained staff including radiation oncologist, clinical medical physicist, and technician (therapist). The optimal radiotherapy treatment can be only performed with close cooperation between all of them. The same radiation however not only harms cancerous tissue, but will also cause damage to healthy tissue. Therefore the radiation beam needs to be precisely targeted to maximize the dose to the target volume cancer, and minimize the dose to the surrounding healthy tissue [1-4].

Small field sizes are defined that those fields of 3 x 3 cm^2 and less in megavoltage photon dosimetry [5-7]. There will be dosimetrical problems associated with these sizes: first, lateral charged particle equilibrium is lost; second, finite size of the X-ray source means that it becomes relatively large compared to the field size. Here, there will be large percentage of field made up by penumbra, and this will add a problem within the detector capacity. Third, finite size of the detector, which means that the perturbation of the radiation field by the detector becomes larger as the field size decreases. [8-10]. The dosimetry of small field is not easy because dose inclination is steep and the lack of lateral electronic equilibrium [11]. T. C. Zhu 2010 recorded that corrections are required to maintain the dosimetric accuracy previously achieved for standard radiation dosimetry [12].

For radiotherapy centers like Zhianawa Cancer Center in Iraq which is deals with new treatment technics such as IMRT, VMAT, and as a rapidly increasing number of tele therapy treatment modalities and techniques. It's very important to know how deal with the new techniques especially in small field dosimetry and what are the factors that effect on it because in the new techniques small fields are used to treat small tumors and minimize effects on the normal tissues. The aim of this study was to provide a document to be a reference and guide for the center through measuring penumbra and output factors using different chambers and photon energies.

Materials and Methods

A wide diversity of measurements of small fields was performed with four different detectors in their optimal field ranges. First of all, measurements were performed with Farmer chamber Type PTW 30013. A set of measurement was performed with a 0.125 cm^3 Semiflex thimble-type 31010 ionization chamber. Another set of measurements was performed with Roos Chamber Type PTW 34001. Measurements of the smallest fields were performed with a 0.015cm3 Pinpoint thimble-type 31006 (PTW, Freiburg, Germany) ionization chamber, in an automatic MP3-M water phantom (PTW, Freiburg, Germany).

Output factors were measured with the Unidos Dosimeter (PTW-Freiburg). A 200V bias was applied to the Roos ion chamber detector, and a bias of 400 V to the Pinpoint, Farmer, and Semiflex chamber. For output factor measurements, the accelerator was set to give a dose rate of 400 monitor units $(MU)min^{-1}$, corresponding to 1 Gy min^{-1} at reference depth (10cm for 6MV and 18MV) for a 10 × 10cm fields and source–detector distance (SDD) of 100cm. The MU readout of the monitor chamber of the linac was used to correct the output rate variations. The precision of positioning within the phantom is 0.1 mm. All measurements were performed with a source-to-surface distance (SSD) of 100cm. The linear accelerator was calibrated to have 1 cGy/MU for a 10 × 10cm^2 field at 10 cm depth and SSD 100cm.

Results and Discussion

Penumbra Measurement

The penumbra measured by the Pinpoint, Roos, Farmer and Semiflex chambers at 10 cm depth, using 6MV and 10 MV photon beam energies for a small field and non-small field which as defined by a conventional MLC. The penumbra for non-small field size (4x4) was 5.7 mm for both Farmer and Semifiex chambers while for Pinpoint chamber was 5 mm and for Roos chamber was 9.9mm. For field size (5x5) the penumbra was (5.6, 6.3, 4.8 and 11.3) mm for Farmer, Semiflex, Pinpoint and Roos chambers respectively. For the last non-small field size (10x10) the penumbra for Farmer, Semiflex, Pinpoint and Roos chambers was (6.3, 6, 4.9 and 11.9)mm respectively, the results shown in Table 1.

Table 1: Penumbra Depth for Non-Small field for 6 MV for MLC Shaped Fields.

Chambers	In-plane Penumbra at $D_{100\,mm}$		
	Field size (4x4)	Field size (5x5)	Field size (10x10)
Farmer chamber	5.7 mm	5.6 mm	6.3 mm
Semi flex Chamber	5.7 mm	6.3 mm	6 mm
Pinpoint chamber	5 mm	4.8 mm	4.9 mm
Roos chamber	9.9 mm	11.3 mm	11.9 mm

Table 2 represents the data for small field sizes. The penumbra for the field size (1x1) was (5.6, 5, 3.5 and 6.3) mm for Farmer, Semiflex, Pinpoint and Roos chambers respectively. For the field size (2x2) it was (5.6, 4.9, 3 and 9.1) mm for Farmer, Semiflex, Pinpoint and Roos chambers respectively and for the field size (3x3) it was (6.3, 4.9, 3.5 and 9.8) mm for the chambers Farmer, Semiflex, Pinpoint and Roos respectively. We observed that penumbra width for different chambers is different. Roos chamber lesser extended than the other chambers and pinpoint chamber slightly broaden due to the volume averaging and the non-water equivalence of an air ion chamber, the higher range of electrons in air than in water results in a broadening of the measured penumbra.

Table 2: Penumbra Depth for Small Field for 6 MV.

Chambers	In-plane Penumbra at D_{100mm}		
	Field size(1x1) Made by MLC	Field size (2x2) Made by MLC	Field size (3x3) Made by MLC
Farmer chamber	5.6 mm	5.6 mm	6.3 mm
Semi flex Chamber	5 mm	4.9 mm	4.9 mm
Pinpoint chamber	3.5 mm	3 mm	3.5 mm
Roos chamber	6.3 mm	9.1 mm	9.8 mm

Table 3: Penumbra Broadening, Penumbra broadening calculated as penumbra for different chambers subtract penumbra reference chamber (Pinpoint).

Chambers	Non-small field (1x1) cm^2	Small Field (10x10) cm^2
Pinpoint chamber	0 mm	0 mm
Semi flex chamber	1.1 mm	1.5 mm
Farmer chamber	1.4 mm	2.1 mm
Roos chamber	7 mm	2.8 mm

Table 3 represents the penumbra broadening measured with the different chambers and field sizes of (1x1and10x10) with

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two photon energies beams (6MV and 10MV). We distinguished the distance between 80%–20% penumbra widths. The measurements were obtained in 10cm depths. The penumbra broadening for non-small field size (10x10) was (0, 1.4, 1.1 and 7)mm and for the small field size (1x1) it was (0, 2.1, 1.5 and 2.8) for Pinpoint, Semiflex, Farmer and Roos chambers respectively.

We observed that the measured penumbra broadening increases with decreasing field sizes due to the volume averaging and the non-water equivalence of an air ion chamber. Choosing a detector for measuring small fields are not easy. M. Yarahmadi et al. showed the Gafchromic EBT2 film is suitable detector for small field dosimetry especially for penumbra and output factor measurements [13]. Air field ionization chamber is in the first for large field while different types of detectors are used for small fields. Solid detectors such as silicon diode are often used now in small field dosimetry [14] and diamond detectors are very suitable for small field measurement [15]. The possibility of the center is limited so in our study we used only Pinpoint, Semiflex, Farmer and Roos chambers.

Output Factors Measurements

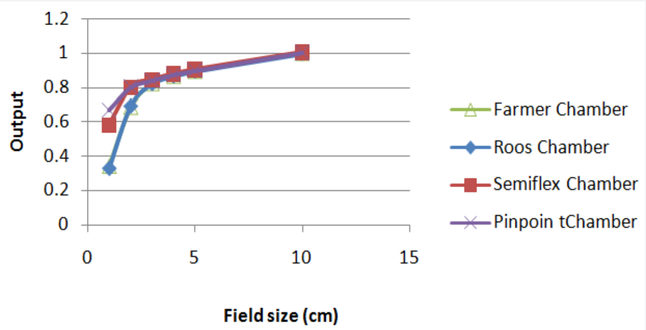

Figure 1: 6 MV Output factor for different ion chambers and different field size.

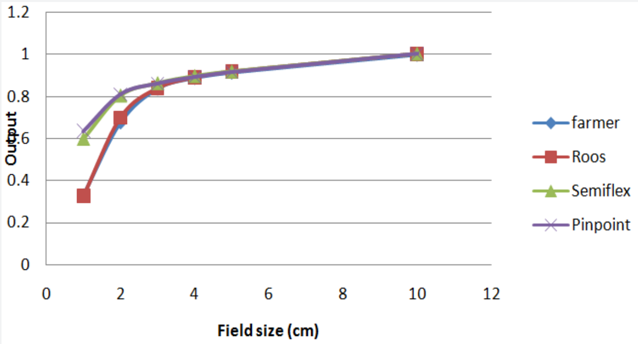

Figure 2: 10 MV Output factor for different ion chambers and different field size.

The output factors were obtained with the four detectors, and different field sizes for two photon energies (6 and 10) MV as shown in Figures 1 & 2. In the non-small field sizes (5 x 5cm) and above the output reading factors value is almost the same, but in the smaller field sizes (3 x 3cm) and below they have different values and this variation increase with decreasing field sizes due to the volume effect of the Pinpoint chamber, the large volume of the chamber, part of the penumbra is integrated into the measured dose in the effective volume of the chamber, and the larger fields, the material and volume dependence of the detectors is minimal. The fact that until (2 x 2cm) field size, the Semiflex and Pinpoint chambers give the same reading, whereas the Farmer and Roos start deviation below (4 x 4cm). It means that clinically, the Semiflex chamber can be used to commission linac until (2 x 2cm) field size.

For small field sizes smaller such as (1 x 1cm), (0.5 x 0.5cm) actually need a micro chamber or films. In no way, commission a linac down to (1 x 1cm) with a Semiflex chamber as this would over-estimate the MU by the 1.14% between the Semiflex and Pinpoint. If the small field (1 x 1cm) commission with Farmer chamber the dose rate at D_{max} will be 3.92 mGy/100 MU its need 669.6 MU to deliver 1Gy to 14cm depth at central axis but for Pinpoint the dose rate will be 6.88 mGy/100 MU and needs 316.75 MU to deliver 1Gy this means that if we calibrate (1 x 1cm) field with Farmer we get error of high dose by 2.11 times. In our study we observed that between the chambers pinpoint is the best for measuring output factors in small fields however in the new study done by F Marsolat et al. [16] they demonstrated that water-equivalent single crystal CVD diamond dosimeter better than a Pinpoint ionization chamber in measuring output factors in a small beam.

Conclusion

Depending on our results we conclude:

i. The size of the chamber has a huge effect on the output factor and penumbra of the beams. The larger the size of the chamber, the larger is the adverse effect on smaller beams. Sometimes the error might reach double of the original value, which would eventually lead to double the dose given to the patient.

ii. The Pinpoint chamber between the chambers in our centers is an excellent choice as a detector for output measurements in IMRT, irrespective of photon energy. For beam penumbra analysis, its performance is superior to that of the other chambers.

iii. Combining measurements performed using more than one dosimetric technique can significantly help towards the reduction or elimination of this uncertainty. This way the clinical outcome of modern technique treatments can be more accurate and reliable.

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References

1. Khan, Faiz M, John P Gibbons (2014) Khan's the physics of radiation therapy. Lippincott Williams & Wilkins, Pennsylvania, USA.
2. Williams Jerry R, David I Thwaites (1993) Radiotherapy physics in practice. Oxford University Press, USA.
3. Boyer Arthur L, Timothy Schultheiss (1988) "Effects of dosimetric and clinical uncertainty on complication-free local tumor control." Radiother Oncol 11(1): 65-71.
4. Murray LJ, MH Robinson (2011) "Radiotherapy: technical aspects." Medicine 39(12): 698-704.
5. Zhu Timothy C, Bengt E Bjärngard, Hobart Shackford (1995) "X-ray source and the output factor." Medical physics 22(6): 793-798.
6. Zhu, Timothy C, Bengt E Bjärngard (1994) "The head-scatter factor for small field sizes." Medical physics 21(1): 65-68.
7. Ding George X, Dennis M Duggan, Charles W Coffey (2006) "Commissioning stereotactic radio surgery beams using both experimental and theoretical methods." Phys Med Biol 51(10): 2549-2566.
8. Boyer Arthur L, Ochran TG, Nyerick CE, Waldron TJ, Huntzinger CJ (1992) "Clinical dosimetry for implementation of a Multileaf collimator." Medical physics 19(5): 1255-1261.
9. Li Shidong, Rashid A, He S, Djajaputra D (2004) "A new approach in dose measurement and error analysis for narrow photon beams (beamlets) shaped by different multileaf collimators using a small detector." Medical physics 31(7): 2020-2032.
10. Jones Andrew O, Indra J Das, Frederick L Jones (2003) "A Monte Carlo study of IMRT beamlets in inhomogeneous media." Medical physics 30(3): 296-300.
11. Hossein Hassani, Hassan Ali Nedaie, Mohammad Hassan Zahmatkesh, Kaveh Shirani (2017) Medical dosimetry 39: 102-107.
12. TC Zhu (2010) Small Field: dosimetry in electron disequilibrium region. Journal of Physics: Conference Series 250, Bristol, England, UK.
13. Yarahmadi M, HA Nediae, M Allahverdi, Kh Asnaashari, OA Sauer (2013) "Small photon field dosimetry using EBT2 Gafchromic film and Monte Carlo simulation." International Journal of Radiation Research 11(4): 215-224.
14. JU Wuerfel (2013) Dose measurements in small fields. Medical Physics international journal, 1(1): 81-90.
15. Wolfram U Lauba, Wong T (2003) The volume effect of detectors in the dosimetry of small fields used in IMRT. Med Phys 30(3): 341-347.
16. F Marsolat, D Tromson, N Tranchant, M Pomorski, D Lazaro-Ponthus, et al. (2013) Diamond dosimeter for small beam stereotactic radiotherapy. Diamond & Related Materials 33: 63-70.

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