International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2024.0297
e ISSN: 2584-2854
Volume: 02
Issue: 06 June 2024
Page No: 2020-2023

Evaluation of High-Resolution Radiation Detectors in Small Field Radiation Measurements

Abdul A A Sait[1], *Nikhil Rastogi*[2], *S P Pandey*[3]

[1]*Research Scholar, Teerthanker Mahaveer University, Moradabad, Moradabad, India.*

[2,3] *Professor, Department of Physics, Teerthanker Mahaveer University, Moradabad, India.*

Email: *abdulazizsait@gmail.com*[1], *drnikhilrastogi75@gmail.com*[2]

Abstract

To investigate the effectiveness of high-resolution detectors in small-radiation-field output factors. Six high-resolution radiation detectors were employed: W2 and W1 plastic scintillators, MicroDiamond, MicroSilicon, Edge detectors and pinpoint 3D micro ionization chamber. The output factors were measured for different beam energies (6MVFF, 6MVFFF, 10MVFF, and 10MVFFF) and field sizes (10 × 10, 5 × 5, 4 × 4, 3 × 3, 2 × 2, 1 × 1, 0.5 × 0.5 cm2) using a Varian True Beam Linear accelerator. The analysis included percentage deviations in the output factors. A comparison of the W2 PSD with other detectors revealed that they were within 3 % agreement for output factors up to a 3 × 3 cm2 field size. However, significant differences were observed beyond a 3 × 3 cm2 area. Our study demonstrated that although the W2 PSD showed good agreement with other detectors for small-field dosimetry up to 3 × 3 cm2, discrepancies occurred beyond this field size.

Keywords: *Detectors; Radiation; Small Field Measurements.*

1. Introduction

Cancer is a significant health problem worldwide and ranks second in terms of mortality. Almost 70% of cancer-related deaths occur in low- and middle-income countries [1]. In approximately half of all cancer cases, radiation therapy is administered in conjunction with either chemotherapy or surgery [2]. The aim of radiation therapy is to deliver an adequate dose to the target, ensuring a desired tumor control probability while minimizing the radiation exposure to the surrounding normal tissue, especially vital structures, to achieve a high therapeutic ratio of potential benefit to risk [3]. In recent years, technological advancements in engineering and physics computing have greatly improved radiation delivery techniques. Treatment planning systems (TPSs) use advanced optimization techniques to create precise clinical treatment plans for intensity-modulated radiation therapy (IMRT), volumetric-modulated arc therapy (VMAT), stereotactic radiosurgery (SRS), and body radiation therapy (SBRT). These complex plans often involve significant dose gradients around and within both target volumes and tissues. Advances in SRS and SBRT techniques have significantly improved the management of small primary and secondary metastases in the brain, lung, abdomen, liver, and spine [4-6]. However, these treatments require rigorous commissioning of beam data and pre-treatment quality verification due to the complex nature of planning and delivery [7, 8]. Acquiring small-field data for radiation dosimetry is a difficult task because of source occlusion, lateral electronic disequilibrium, and the choice of measuring detector [9, 10]. Radiation detectors are the primary tools used to measure radiation, particularly during the commissioning of radiation machines, quality assurance (QA), and additional treatment dose verification. Small fields, which are treatment fields smaller than 3 × 3 cm2 [11], are primarily used in stereotactic treatment techniques for various anatomical locations. Due to the intricate nature of small-field beam characteristics, such as source occlusion, lateral electronic disequilibrium, and the delicate size of the detector, small-field measurements and commissioning are difficult and time-consuming activities. There are various high-

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2024.0297
e ISSN: 2584-2854
Volume: 02
Issue: 06 June 2024
Page No: 2020-2023

resolution radiation detectors available in the market, including ionization chambers, diode detectors, gel dosimetry, film dosimetry, and scintillation detectors. Small-field dosimetry is a critical aspect of radiation therapy that demands precise attention, as even minor errors can result in significant dose misadministration. Since the 1950s, researchers have been working to develop detectors that are suitable for small-field measurements. Due to the various challenges associated with these measurements, detector-specific correction factors have been derived to accurately calculate doses in small fields [12]. The difficulties in small-field dosimetry result from the physical characteristics of the fields themselves, which can measure only a few millimeters in diameter. Given that conventional detectors can be too large to provide precise readings in such confined spaces, specialized detectors have been developed and employed to ensure higher resolution and accuracy in radiation measurement [13]. International task groups have consistently provided recommendations for the accurate measurement of small field dosimetry and the beam modeling for small field applications. Corresponding correction factors have been tabulated in the guidelines for various radiation detectors. Notable task groups include the International Atomic Energy Agency (IAEA) report 483 [14], the American Association of Physicists in Medicine (AAPM) Task Group 155 [15], and the Institute of Physics and Engineering in Medicine (IPEM) report 103 [16]. The aim of our study was to compare various high-resolution detectors in small field dosimetry for output factor measurements.

2. Method

Six high-resolution detectors were selected to measure small fields in a TrueBeam linear accelerator (LINAC) (Figure 1). The detectors used in this study included the Standard Imaging Exradin W2 (1x1 mm²) Plastic Scintillator Detector (PSD), the Exradin W1 (1x3 mm²) PSD, the Sun Nuclear Corporation (SNC) Edge Detector, the PTW microSilicon (60023), the PTW microDiamond (60019), and the PTW pinpoint three-dimensional ionization chamber (PTW31022). A SNC 3D tank and an acrylic water phantom (used only for the W1PSD and EPID detectors) were employed to measure the output factors for various photon energies: 6 MV with Flattening Filter (FF), 6 MV Flattening Filter Free (FFF), 10 MV FF, and 10 MV FFF. The jaw-defined field sizes included 10x10 cm², 5x5 cm², 4x4 cm², 3x3 cm², 2x2 cm², 1x1 cm², and 0.5x0.5 cm². The source-to-axis distance (SAD) output factors were measured at a source-to-surface distance (SSD) of 95 cm, with the corresponding detector placed at a depth of 5 cm, and an SAD of 100 cm. The W2PSD was set up in a 3D tank (Figure 1) using a specially designed 3D-printed holder. The W1PSD was used exclusively to measure the output factor with the acrylic water phantom, as the SNC dosimetry software version 3.4 did not support depth dose and profile measurements with the W1PSD. Cerenkov light ratio (CLR) correction calibrations for both the W1 and W2 PSDs were performed according to the standard imaging Exradin CLR calibration procedures. All detector measurements were compared against the reference measurements conducted using the W2PSD. The analysis involved calculating the percentage deviations in the output factors across all detectors and four radiation energies. This comprehensive comparison aimed to evaluate the performance and accuracy of each high-resolution detector in small field dosimetry.

Figure 1 Linac with A Measurement Water Tank

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2024.0297
e ISSN: 2584-2854
Volume: 02
Issue: 06 June 2024
Page No: 2020-2023

3. Results and Discussion

3.1. Results

The study compared various high-resolution detectors against the Standard Imaging Exradin W2 Plastic Scintillator Detector (W2PSD) for output factor measurements, across different field sizes and photon energies. The results were normalized to a 10x10 cm² field size and analyzed for percentage deviations. The Edge Detector showed deviations ranging from 1.2% to 2.3% when compared to the W2PSD, with the highest deviation of ±2.5% observed for the smallest field size of 0.5x0.5 cm². This indicates a relatively stable performance across most field sizes, but with slightly higher deviations in the smallest fields. The microSilicon, W1PSD, and microDiamond detectors generally displayed deviations below 2%. However, the microDiamond detector had significant underestimations in the 0.5x0.5 cm² field, with deviations reaching up to -18%. This underestimation highlights a potential limitation of the microDiamond detector in very small field dosimetry. For field sizes up to 2x2 cm², the ionization chamber exhibited deviations below 1.3%. However, for the smallest field size of 0.5x0.5 cm², there was a substantial underestimation of up to -80%. This significant deviation suggests that the ionization chamber is not suitable for very small field sizes below 2x2 cm². W2PSD vs. Edge Detector; The Edge Detector showed mean percentage deviations of 1.6±0.6% for 6X, 1.2±0.9% for 6FFF, 2.3±0.6% for 10X, and 2.2±0.4% for 10FFF. The maximum deviation of ±2.5% was observed for the 0.5x0.5 cm² field size across all energies. W2PSD vs. MicroSilicon Detector; The deviations for the microSilicon Detector were 1.2±0.7% for 6X, 1.0±0.5% for 6FFF, 1.6±0.6% for 10X, and 1.2±0.2% for 10FFF. These results indicate relatively consistent performance across different energies and field sizes. W2PSD vs. W1PSD; The W1PSD exhibited deviations of 1.5±0.5% for 6X, 0.9±0.3% for 6FFF, 1.3±0.5% for 10X, and 1.2±0.5% for 10FFF. The deviations were generally within acceptable limits, demonstrating the W1PSD's reliability in small field dosimetry. W2PSD vs. MicroDiamond Detector; The microDiamond Detector showed mean percentage deviations of 1.5±0.4% for 6X, 0.8±0.7% for 6FFF, 1.8±0.6% for 10X, and 1.6±0.8% for 10FFF. However, significant underestimations were noted for the 0.5x0.5 cm² field size, with deviations of 18% for 6X, 17% for 6FFF, 10% for 10X, and 11% for 10FFF. W2PSD vs. Ionization Chamber; For field sizes up to 2x2 cm², the ionization chamber exhibited deviations of 0.8±0.4% for 6X, 0.6±0.4% for 6FFF, 1.3±0.6% for 10X, and 1.1±0.2% for 10FFF. For the 1x1 cm² field size, an average maximum deviation of 10% underestimation was observed across all energies. The 0.5x0.5 cm² field size showed a substantial average maximum deviation of 80% underestimation, aligning with previous studies and indicating the ionization chamber's unsuitability for very small fields.

3.2. Discussion

The results of this study provide a comparison of various high-resolution detectors used in small field dosimetry, focusing on their performance in measuring output factors across different field sizes and photon energies. The discussion addresses the key findings, their implications, and the potential limitations of the detectors evaluated. These results indicate that the Edge Detector performs consistently across most field sizes, but its accuracy diminishes slightly in the smallest fields. This performance aligns with previous studies, which have shown that the Edge Detector is generally reliable but require careful calibration and correction factors for very small fields. The microSilicon, W1PSD, and microDiamond detectors exhibited deviations below 2% for most field sizes, demonstrating good overall performance. This finding suggests that while the microDiamond detector is suitable for small fields with appropriate correction factors. The findings of this study have important implications for clinical practice. Accurate measurement of small field dosimetry is crucial for ensuring effective and safe radiation therapy, particularly in advanced techniques such as SRS and SBRT. The results suggest that while most high-resolution detectors perform well for larger fields, significant deviations in smaller fields necessitate careful selection and calibration of detectors. Clinicians should be aware of the limitations of each detector and apply appropriate correction factors to ensure accurate dosimetry in

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2024.0297
e ISSN: 2584-2854
Volume: 02
Issue: 06 June 2024
Page No: 2020-2023

small fields. Future studies should explore a wider range of detectors and equipment to validate the findings. Additionally, further research is needed to develop and refine correction factors for small field dosimetry, particularly for detectors that exhibit significant deviations in small fields.

Conclusion

In conclusion, this study provides valuable insights into the performance of various high-resolution detectors in small field output factor dosimetry. While most detectors showed good agreement with the W2PSD for larger fields, significant deviations were observed in the smallest fields for the microDiamond and ionization chamber detectors. These findings highlights the importance of careful detector selection and calibration in clinical practice to ensure accurate and effective radiation therapy.

References

[1]. WHO fact Sheet https://www.who.int/news-room/fact-sheets/detail/cancer.
[2]. Delaney G, Jacob S, Featherstone C, Barton M. The role of radiotherapy in cancer treatment: Estimating optimal utilization from a review of evidence-based clinical guidelines. Cancer. 2005; 104:1129–37.
[3]. Williamson JF, Dunscombe PB, Sharpe MB, Thomadsen BR, Purdy JA, Deye JA, et al. Quality assurance needs for modern image-based radiotherapy: Recommendations from 2007 interorganizational symposium on "quality assurance of radiation therapy: Challenges of advanced technology" Int J Radiat Oncol Biol Phys. 2008;71: S2–12.
[4]. L. Leksell, The stereotaxic method and radiosurgery of the brain, Acta Chir. Scand. 102, 316-319 (1951).
[5]. Lutz W, Winston KR, Maleki N. A system for stereotactic radiosurgery with a linear accelerator. Int J Radiat Oncol Biol Phys. 1988 Feb; 14(2):373–81.
[6]. Chen, J. C., & Girvigian, M. R. (2005). Stereotactic radiosurgery: instrumentation and theoretical aspects-part 1. The Permanente journal, 9(4), 23–26.
[7]. Brahme A. Dosimetric precision requirements in radiation therapy. Acta Radiol Oncol. 1984; 23:379–91.
[8]. Brahme A. Accuracy requirements and quality assurance of external beam therapy with photons and electrons. Acta Oncol 1988; suppl 1:5–76.
[9]. Das, I.J., Ding, G.X. and Ahnesjö, A. (2008), Small fields: Nonequilibrium radiation dosimetry. Med. Phys., 35: 206-215.
[10]. Charles, P.H., Cranmer-Sargison, G., Thwaites, D.I., Crowe, S.B., Kairn, T., Knight, R.T., Kenny, J., Langton, C.M. and Trapp, J.V. (2014), A practical and theoretical definition of very small field size for radiotherapy output factor measurements. Med. Phys., 41: 041707.
[11]. Das, IJ, Francescon, P, Moran, JM, et al. Report of AAPM Task Group 155: Megavoltage photon beam dosimetry in small fields and non-equilibrium conditions. Med Phys 2021; 48: e886–e921.
[12]. S.E. Lam, D.A. Bradley, M.U. Khandaker. Small-field radiotherapy photon beam output evaluation: Detectors reviewed. Radiation Physics and Chemistry. Volume 178, 2021,108950, ISSN 0969-806X.
[13]. Kron T, Lehmann J, Greer PB. Dosimetry of ionising radiation in modern radiation oncology. Phys Med Biol. 2016; 61:R167–205.
[14]. International Atomic Energy Agency, Dosimetry of Small Static Fields Used in External Beam Radiotherapy, Technical Reports Series No. 483, IAEA, Vienna (2017).
[15]. Das, IJ, Francescon, P, Moran, JM, et al. Report of AAPM Task Group 155: Megavoltage photon beam dosimetry in small fields and non-equilibrium conditions. Med Phys 2021; 48: e886–e921.
[16]. Aspradakis M, Byrne J, Palmans H, Conway J, Rosser K, Warrington J, et al. Small field MV photon dosimetry. IPEM Report No. 103, Institute of Physics and Engineering in Medicine, York, UK. 2010.