RESEARCH ARTICLE

The evaluation of the two-dimensional gamma passing rate efficiency for the unilateral breast cancer dosimetry using the Intensity-Modulated Radiation Therapy

Afnan Fouad Al-Wakeel[1], Mustafa Salih. Al Musawi[2], Hayder Hamza Alabedi[3]

Abstract

Objective: To evaluate the efficacy of the commonly used two-dimensional gamma passing rate of 3%/3mm for females with unilateral breast cancer.

Method: The cross-sectional study was conducted at Al-Andalus Private Hospital, Baghdad, Iraq, from November 2021 to April 2022 after approval from the Medical Physics and Physiology Department of Mustansiriyah University, Baghdad, and comprised female patients with unilateral breast carcinomas. All the patients were subjected to a computed tomography simulation, and data was transferred to treatment planning system Monaco 5.1 for contouring and planning. An intensity-modulated radiation therapy method was selected. The planning comprised phantom detector and linear agility accelerator for pre-treatment verification. All patients were evaluated using two alternative dosimetry methods: 3%/3mm and 3%/2mm at the threshold of 10% and 5%. The Two-dimensional gamma analysis took each transversal slice in the simulation image for comparison. Data was analysed using SPSS 24.

Results: There were 15 female patients aged 26-65 years. There was a better impact of 3%/3mm compared to 3%/2mm criterion for 5% and 10% thresholds. The proportion was 10% higher than the cutoff point of 5%.

Conclusion: The 3%/2mm criterion should be used for plans that give a high dosage to organs at risk, while the 3 %/3 mm criterion should be used for uncomplicated situations with moderate dosages to at-risk organs.

Key Words: Unilateral Breast, Tomography, Radiotherapy.

(JPMA 74: S318 (Supple-8); 2024) **DOI: https://doi.org/10.47391/JPMA-BAGH-16-73**

Introduction

One of the recent techniques used in radiation therapy for cancer is the use of an X-ray photon[1] or electron[2–4] beam with intensity-modulated fields[5,6]. These fields vary during the treatment continuously and are called dynamic, or moved with steps, and the so-called step-and-shoot fields[7]. Generally, radiotherapy (RT) is essential for cancer patients to eliminate cancerous cells from invading the healthy organs because radiation interacts with both diseased and healthy tissues[8,9]. Breast cancer is one of the most common cancers affecting women worldwide. The risk of this type of cancer is revealed in its position close to the heart and lungs[10,11]. The cancers that fit the intensity-modulated radiation therapy (IMRT) technique need a pretreatment domestic checkup with phantoms for quality assurance[12]. The most efficient algorithm that can evaluate and compare the calculated dose and the real dose delivered to the patient is the gamma index (GI), with magnitude ranging from 0 to 1[12–15]. The calculations satisfying a condition is called the gamma passing rate (%GP) which measures the percentage of all the included points. The GI had two types: local and global. The global GI analysis calculates the percent dose difference (DD) relative to the maximum dose, or prescription dose. The local GI analysis calculates the DD relative to the doses at each evaluated point[16].

Pulliam et al. in 2014[17] compared the two-dimensional (2D) and three-dimensional (3D) %GP results for different treatment site plans with the IMRT technique at different criteria and thresholds. They claimed that the 2D %GP was lower with 2.9% than the 3D %GP. Zhang et al. in 2018[18] compared the two analyses to find the sensitivity of the error detection in IMRT irradiation, using 3%/3mm criteria for prostate cancer patients. They found that the studied criteria were insufficient for detecting the monitor units and multileaf collimator errors. They proposed that a more restricted criteria must be tested to improve the sensitivity.

The American Association of Physics in Medicine (AAPM) in 2018 published the analytical result of many studies, and suggested that 3%/2mm could be better than the

[1-3]Al-Andalus Private Hospital, Baghdad, Iraq

Current Affiliation:

(Author-1-2): Department of Physiology, Mustansiriyah University, Baghdad, Iraq.

(Author-3): Department of Surgery, Baghdad University, Baghdad, Iraq.

Correspondence: Afnan Fouad Al-Wakeel

Email: afnan_mph@yahoo.com

other criteria[19].

The current study was planned to compare the traditional 3%/3mm criterion and the AAPM 3%/2mm criteria in cases of female breast cancer.

Materials and Methods

The cross-sectional study was conducted at Al-Andalus Private Hospital, Baghdad, Iraq, from November 2021 to April 2022 after approval from the Medical Physics and Physiology Department of Mustansiriyah University, Baghdad, and comprised female patients with unilateral breast carcinomas who were enrolled using convenience non-probability sampling technique after taking verbal consent. Alll of them had been treated previously with chemotherapy and breast conservative surgery.

All the patients were scanned using a computed tomography (CT) simulation, and data was transferred to treatment planning system (TPS) using step-and-shoot IMRT (SS-IMRT). An agility linear accelerator (Agility, Elekta, Sweden) was used to treat patients with a 6MV or 10MV energy X-ray photon beam. TPS data was applied to a detector-phantom (Octavius 4D-729, PTW, Freiburg, Germany). All patients were evaluated using 3%/3mm and 3%/2mm dosimetry methods at the threshold of 10% and 5%. The threshold meant the percentage of the maximum dose delivered to the patient <5% or <10% were excluded. The dose measurement was calculated for the two dimensions, and local and global effects were examined[20]. The 2D gamma analysis took each transversal slice in the CT simulation image and compared it with the image generated in the phantom geometry.

Data was analysed using SPSS 24. Data was presented as mean and standard deviation. Comparison was done using paird t-test. p<0.05 was taken as significant.

Results

There were 15 female patients aged 26-65 years. The statistical analysis of the two-dimensional gamma passing rate tested for the local and global %GP at threshold 5%

Table-1: The relationship between gamma passing rate (%GP) and the two studied criteria: 3%/2mm and 3%/3mm at 5% and 10% thresholds..

	5% threshold		
%GP	3%/3 mm	3%/2 mm	p-value
Local	89.98 ± 7.66	82.11 ± 10.79	<0.00001
Global	98.25 ± 3.16	96.25 ± 5.33	0.00632
10% threshold			
%GP	3%/3 mm	3%/2 mm	p-value
Local	93.25 ± 7.87	86.26 ± 11.32	<0.00001
Global	98.06 ± 3.50	95.84 ± 5.86	0.5628

Table-2: Comparison between the 5% and 10% thresholds for 3%/2mm and 3%/3mm criteria

%GP	3%/3 mm	3%/2 mm
G%Local	0.0003	<0.00001
%Global	0.0561	0.01488

%GP: Gamma passing rate.

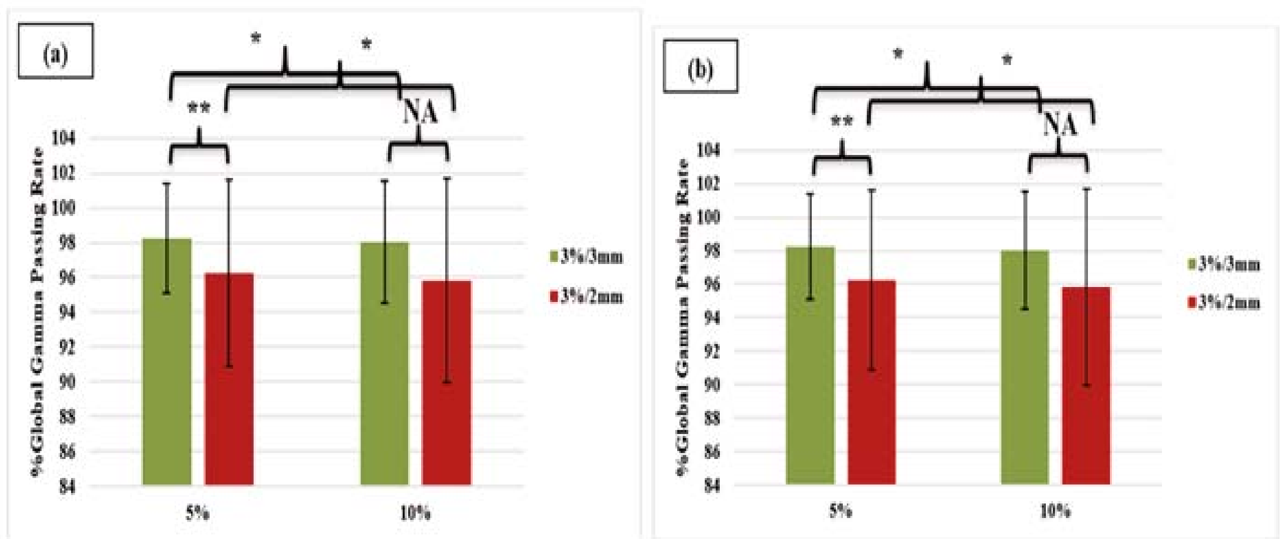

Figure: The two-dimensional (2D) proportion of gamma passing rate (%GP) comparison between 3%/3mm and 3%/2mm criteria.
(a). Local. (b). Global

and 10% as illustrated in Table (1) and Figure (1), respectively. The results show a significant difference between the criteria of 3%/ 3mm and 3%/ 2 mm at threshold of 5% for both local and global %GP. The significancy of local %GP was higher than the global. For the threshold of 10%, there was a highly significant difference between the 3%/ 3mm for the local %GP. No significant difference found between the studied criteria for global %GP at 10% threshold.

A comparative analysis performed for testing the significant difference of local and global 2D gamma passing rate between the two studied thresholds to show the effect on the gamma results. The statistical analysis of comparison shown in Table (2). The comparison shows a highly significant difference between the 5% and 10% for both criteria

Discussion

The cuurent study compared two different DDs and distance to agreement (DTA) criteria for 3%/3mm and 3%/2 mm for two different low-dose thresholds of 5% and 10 %). From the evaluated IMRT plan, the decreasing DD had the greatest significant effect on %GP results. The use of different low-dose thresholds also had a significant effect on %GP. The effect of excluding 10% of the low-dose region showed a worse effect on %GP at 5% threshold for the global %GP, which means that a higher number of pixels failed to pass both the studied criteria. The effect was barely noticeable for the 3%/3mm criteria, but was higher when the 3%/2mm was used. These results agreed with Pulliam KB, et al.[21], who tested both the 2D and 3D gamma indices and found that the %GP rate decreased when the threshold increased. The difference between the global and local %GP is due to a broad low-dose area for DD used in the 2criteria. A study[20] found that most radiotherapy centres used thresholds ranging between 0% and 10%. A study favoured the connection between dosimetric inaccuracy and %GP to evaluate the results of the real dose given to the patients[22]. It should be noted that the 2D of %GP calculation algorithms were the conventional version of the 3D gamma analysis. It takes only the X and Y axis, while the 3D gamma analysis allows the calculation of the entire dose distribution for the patient through volumetric algorithm[23,24].

Nelms et al.[25] observed a lack of association between conventional IMRT Quality Assurance (QA)% of global GP performance and dose variations in crucial anatomic regions of interest. They only used the 3%/3mm criteria with a threshold requirement of 10%. Bailey et al.[26] evaluated neck and head plans and prostate cancer cases at 3%/3mm and 2%/2mm for local and global GP, and reported findings in line with those of the current study.

The essential issue is examining the spatial and dosimetric discrepancies in comparing dosage delivery. Generally, DTA signifies the distance between the two distributions' normal properties. Dosage distributions are generally represented as point arrays, each characterised by position and dose value. The DTA indicates the space between points, leading to spatial dose distribution resolution. Whenever DTA declines, the Octavius-4D phantom detector is used in IMRT Quality Assurance (QA) to improve resolution.

Limitation: The current study has limitations as the sample size was not calculated which could have affected the power of the study.

Conclusion

The 2D %GP analysis was sensitive to errors in dose distribution. The more restricted criteria 3%/2mm resulted in more sensitivity of the doe errors than the 3%/3mm use. The local %GP showed less sensitivity to the low-dose regions, while the global analysis decreased with the percentage of excluded low-dose regions

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: None.

References

1. Pulliam KB, Huang JY, Howell RM, Followill D, Bosca R, O'Daniel J, et al. Comparison of 2D and 3D gamma analyses. Med Phys 2014;41:021710. doi: 10.1118/1.4860195.
2. Nelms BE, Zhen H, Tomé WA. Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors. Med Phys 2011;38:1037-44. doi: 10.1118/1.3544657.
3. Alani EA, Almusawi MS, Mahdi AH. Evaluation the role of Vitamin C as a radiation protective agent using γ -h2ax for signaling of dna damage on irradiated mice testis. Per Tchê Quim 2020;17:128-39. DOI: 10.52571/PTQ.v17.n36.2020.144.
4. Sabbar AR, Abdullah SS, Alabedi HH, Alazawy NM, Al-Musawi MJ. Electron Beam Profile Assessment of Linear Accelerator Using Startrack Quality Assurance Device. J Phys Conf Ser 2021;1829:012015. DOI: 10.1088/1742-6596/1829/1/012015.
5. Sami S, Hameed BS, Alazawy NM, Al-Musawi MJ. Measurements of Electron Beam Dose Distributions in Perspex Block for Different Field Size. J Phys Conf Ser 2021;1829:012025. DOI: 10.1088/1742-6596/1829/1/012025.
6. Alwakeel AF, Al Musawi MS, Alabedi HH, Mohammed HJ. Dosimetric assessment of IMRT treatment planning for unilateral breast cancer patient using Octavius phantom detector. Appl Nanosci 2021;29:1–8. Doi: 10.1007/s13204-021-01836-1.
7. Al Alani EA, Al Musawi MS, Mahdi AH. Influence of vitamin C on irradiated mice tissues induced DNA double strand breaks DSB using gH2AX marker. J Pak Med Assoc 2021;71(Suppl 8):s117-22.
8. Claudino WM, Biganzoli L. Cancer: Principles and Practice of Oncology. Eur J Cancer 2007;16:94. DOI: 10.1111/j.1365-

2354.2006.00680.x.

9. Faraj MK, Al-Musawi MS, Abdulameer AT. Design and manufacturing of a head mask for fixation in stereotactic radiosurgery by the Gamma Knife® Icon™. Surg Neurol Int 2023;14:188. doi: 10.25259/SNI_1053_2022.
10. Madlool SA, Abdullah SS, Alabedi HH, Alazawy N, Al-Musawi MJ, Saad D, et al. Optimum Treatment Planning Technique Evaluation For Synchronous Bilateral Breast Cancer With Left Side Supraclavicular Lymph Nodes. Iran J Med Phys 2020;6:414-20. Doi: 10.22038/IJMP.2020.49211.1791.
11. Low DA, Moran JM, Dempsey JF, Dong L, Oldham M. Dosimetry tools and techniques for IMRT. Med Phys 2011;38:1313-38. doi: 10.1118/1.3514120.
12. Abdulbaqi AM, Abdullah SS, Alabedi HH, Alazawy Nabaa, Al-Musawi MJ, Heydar AF, et al. The effect of total fields' area and dose distribution in step and shoot IMRT on gamma passing rate using OCTAVIUS 4D-1500 detector phantom . Iran J Med Phys 2020;18:226-31. Doi: 10.22038/IJMP.2020.44712.1690.
13. Ezzell GA, Burmeister JW, Dogan N, LoSasso TJ, Mechalakos JG, Mihailidis D, et al. IMRT commissioning: multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119. Med Phys 2009;36:5359-73. doi: 10.1118/1.3238104.
14. Esch AV, Basta K, Evrard M, Ghislain M, Sergent F, Huyskens DP, et al. The Octavius1500 2D ion chamber array and its associated phantoms: dosimetric characterization of a new prototype. Med Phys 2014;41:091708. doi: 10.1118/1.4892178.
15. Moran JM, Radawski J, Fraass BA. A dose gradient analysis tool for IMRT QA. J Appl Clin Med Phys 2005;6:62-73. doi: 10.1120/jacmp.v6i2.2006.
16. Pulliam KB, Huang JY, Howell RM, Followill D, Bosca R, O'Daniel J, et al. Comparison of 2D and 3D gamma analyses. Med Phys 2014;41:021710. doi: 10.1118/1.4860195.
17. Zhang D, Wang B, Zhang G, Ma C, Deng X. Comparison of 3D and 2D gamma passing rate criteria for detection sensitivity to IMRT delivery errors. J Appl Clin Med Phys 2018;19:230-8. doi: 10.1002/acm2.12389.
18. Miften M, Olch A, Mihailidis D, Moran J, Pawlicki T, Molineu A, et al. Tolerance limits and methodologies for IMRT measurement-based verification QA: Recommendations of AAPM Task Group No. 218. Med Phys 2018;45:e53-83. doi: 10.1002/mp.12810.
19. Nelms BE, Simon JA. A survey on planar IMRT QA analysis. J Appl Clin Med Phys 2007;8:76-90. doi: 10.1120/jacmp.v8i3.2448.
20. In: Dyk JV, eds. Radiation Oncology Medical Physics Resources for Working, Teaching, and Learning. The Modern Technology of Radiation Oncology, 1st ed. Madison, Wisconsin: Medical Physics Publishing, 2013; pp 1–52.
21. Wu C, Hosier KE, Beck KE, Radevic MB, Lehmann J, Zhang HH, et al. On using 3D γ-analysis for IMRT and VMAT pretreatment plan QA. Med Phys 2012;39:3051-9. doi: 10.1118/1.4711755.
22. Wendling M, Zijp LJ, McDermott LN, Smit EJ, Sonke JJ, Mijnheer BJ, et al. A fast algorithm for gamma evaluation in 3D. Med Phys 2007;34:1647-54. doi: 10.1118/1.2721657.
23. Bailey DW, Nelms BE, Attwood K, Kumaraswamy L, Podgorsak MB. Statistical variability and confidence intervals for planar dose QA pass rates. Med Phys 2011;38:6053-64. doi: 10.1118/1.3651695.