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Dosimetric Verification of Gamma Passing Rate for Head and Neck Cases Treated with Intensity Modulated Radiation Therapy (IMRT) Treatment Planning Technique

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Abstract:

Each Intensity Modulated Radiation Therapy (IMRT) plan needs to be tested and verified before any treatment to check its quality. Octavius 4D-1500 phantom detector is a modern and qualified device for quality assurance procedure. This study aims to compare the common dosimetric criteria 3%/3 mm with 2%/2 mm for H&N plans for the IMRT technique. Twenty-five patients with head and neck (H&N) tumor were with 6MV x-ray photon beam using Monaco 5.1 treatment planning software and exported to Elekta synergy linear accelerator then tested for pretreatment verification study using Octavius 4D-1500 phantom detector. The difference between planned and measured dose were assessed by using local and global gamma index (GI) analysis method at threshold 10%. The DD/DTA criteria are performed with 3%/3 mm and 2%/2 mm. A significant difference is shown between the measured and calculated point dose for the treatment plans. A comparison made between the gamma passing rate between the 2%/2 mm and 3%/3 mm shows a significant difference for local and global which shows that the 2%/2 mm are more sensitive to dose variation than 3%/3 mm. The total monitor unit (MU) shows a negative linear relationship with both criteria and %GP types. A significant correlation is shown between the total MU and global %GP at 2%/2 mm criterion. The conclusion of the study indicates that 2%/2 mm criterion is more sensitive to the dose distribution changes than the 3%/3 mm. The total number of monitor units should be taken into consideration during the planning of H&N tumors using the IMRT plans.

Keywords: Gamma Index**,** IMRT, Monitor Unit, Octavius.

1. Introduction:

The modern radiation therapy treatment of Head and Neck (H&N) tumors are done with a treatment planning technique named intensity-modulated radiation therapy or so-called IMRT. The IMRT delivers the non-uniform intensity of eternal radiation across the beams to the target volume to optimize the composite dose distribution [1,2]. The quality assurance (QA) program includes all aspects of the patient's treatment process such as linear accelerator QA, imaging guidance for treatment planning, patient-specific IMRT measurements, and data transfer[3]. The unit that measures the output dose from the linear accelerator machine (linac) is called the monitor unit (MU) which is equal to 100 Gy [4-6]. For IMRT and VMAT. PTW (PTW, Freiburg, Germany) invent a device called Octavius 4D with 1500 cubic ion chambers distributed over the 27 × 27 cm^2 detector surfaces contain a place inserted with the 2D array. It uses software named Verisoft 7.1 software version. To assess the delivery accuracy and verify the IMRT plans, a gamma evaluation method adopted which is proposed by Low in 1998 [7,8]. Gamma evaluation is a practical method where its verification varies from one QA device to another[9]. Many studies discussed and tested the gamma method in many clinical institutions for various criteria and devices[10-12]. Gamma index (GI) results from the algorithm relationship between the percentage of dose difference (%DD) and distance to agreement (DTA) measured in mm[13-15]. The gamma index typically is categorized into two types: local and global. The main difference between them occurs in the method of evaluating the dose difference[16-18].

Stasi *et al* [19] studied different GI parameters and thresholds. The researchers noted that there was a big amount of variability concerning the result of %GP. With the gamma standard that was set with 3%/3 mm, it was found that the total passing rate of

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local normalization is less on the average in comparison with the global one by 4.6%. In addition to that the big diversity between %GP that is measured using the local or global method has been established through an unpaired *t*-test statistical evaluation. The American association of physics in medicine (AAPM) published a report for many studies and revealed that the 3%/3 mm criteria are the most commonly used in pretreatment IMRT QA[20].

This study aims to compare the common gamma dosimetric criteria which are 3%/3 mm and 2%/2 mm of head and neck tumors for IMRT treatment planning technique plans. Also, to assess their relationship with a total number of monitor units to improve their future planning and program verification results.

2. Materials and Methods:

In the proposed investigation, twenty-five patients with H&N tumors with both genders (female and male) aged from 25 – 60 years collected from "Baghdad Radiotherapy and Nuclear Medicine Center" were enrolled firstly for CT simulation (Philips company, Netherland). Then, their anatomical images were exported to the IMRT planning system with Step and Shoot (SS) type via Monaco TPS (version 5.1, Elekta, Sweden) with 6 MV x-ray photon beams. To evaluate the H&N IMRT plans and to examine the accuracy of radiation delivery, QA OCTAVIUS 4D-1500 detector phantom (PTW-Freiburg, Germany) was employed. Subsequently, the data obtained were analyzed using Verisoft 7.1 software (PTW-Freiburg, Germany). Concurrently, the recorded data using TPS were compared with the measured ones through phantom using the gamma index approach. Hereinafter, %GP was estimated locally and globally using 3%/3 as well as 2%/2 mm.

2.1 Statistical Analysis:

The analysis of the reported study was performed using Statistical Packages (SPSS-24) in which the significance of different means was tested through the Students-test. Whilst, the correlation test values were attained using Spearman rank calculator as well as the Scattering distribution curve. The statistical significance/p-value was evaluated at a 0.5 level.

3. Results:

The results obtained from the %GP for 3%/3mm and 2%/2mm criteria are illustrated in Fig. 1, in which it can be observed that local and global %GP 3%/3mm are higher than 2%/2mm. Additionally, the statistical evaluation, which reveals a significant difference between both utilized criteria, is tabulated in Tab. 1. In particular, the local and global %GP for 3%/3mm were found to be 19% and 12% higher than those in the case of 2%/2mm, respectively. This indicates that 2%/2mm highly influenced by the output variation in comparison to 3%/3mm; where a high standard deviation was noticed.

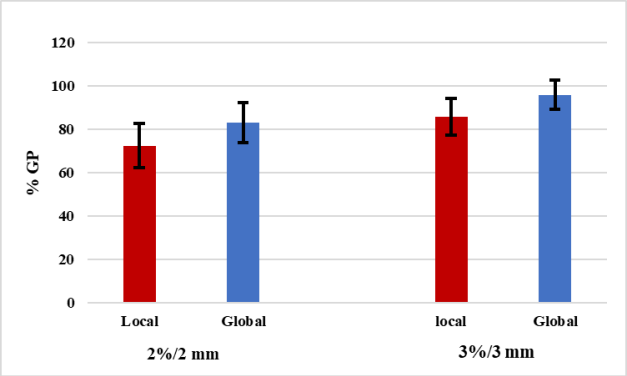

Figure 1. Comparison of mean global and local %GP for 2%/2mm and 3%/3mm.

Table 1. comparison between the %GP criteria for local and global

%GP Method	3%/3 mm	2%/2 mm	p-value
Local	85.72 ± 7.40	72.43 ± 10.14	< 0.00001
Global	95.42± 5.65	83.09± 9.14	< 0.00001

T-Test for Independent Means Statistical Analysis at Significant Level < 0.05

The correlation between MU and %GP outcomes are depicted in Tab. 2, which was attained using the MU number for both 2%/2mm and 3%/3mm. In a general inspection of Tab.2, a decrease in the value of both 2%/2mm and 3%/3mm %GP was perceived as the MU number increased. Furthermore, the scatter plots are elucidated in Figs. 2, 3, 4, and 5; where a negative linear relation is elaborated between the total MU number and %GP.

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Table 2. Correlation between the Monitor Unit (MU) criteria for local and global

%GP Method	3%/3 mm		2%/2 mm	
	r_s – value	*p* - value	r_s – value	*p* – value
Local	0.34776	0.08849	-0.42931	0.03222
Global	-0.52358	0.00723	-0.51692	0.00815

Spearman's Rank Calculator Correlation Coefficient Statistical Analysis at Significant Level < 0.05

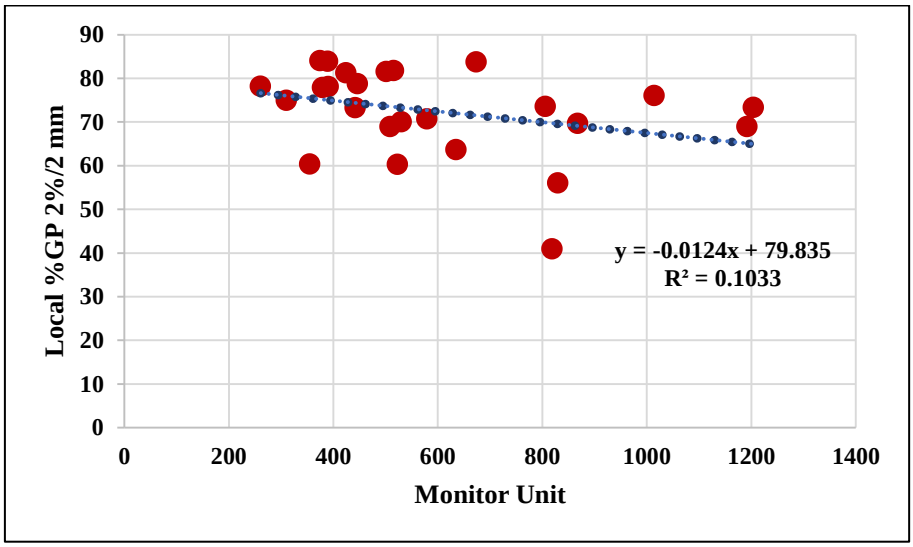

Figure 2. Linear relation between the total number of monitoring units for IMRT plans and local %GP at 2%/2mm.

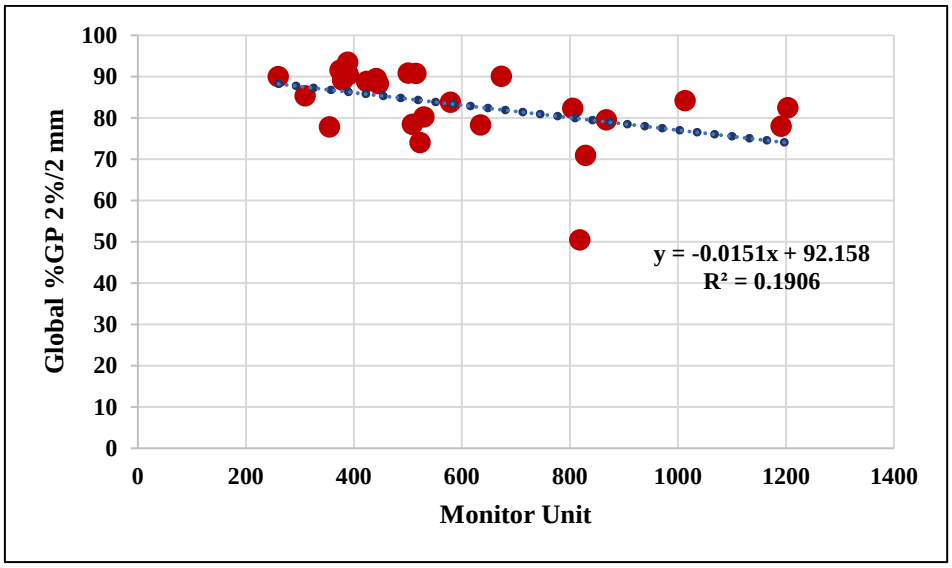

Figure 3. Linear relation between the total number of monitoring units for IMRT plans and global %GP at 2%/2mm.

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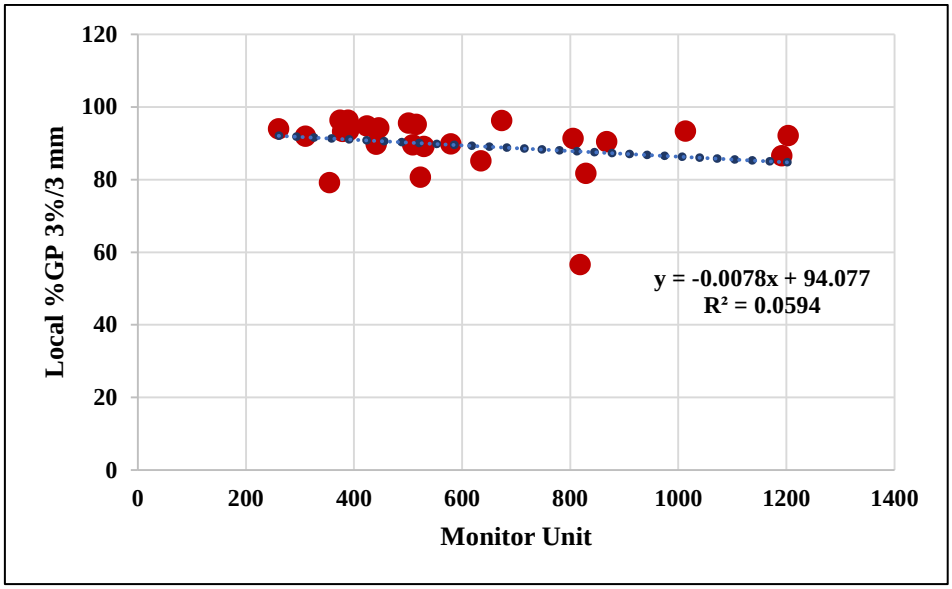

Figure 4. Linear relation between the total number of monitoring units for IMRT plans and local %GP at 3%/3mm.

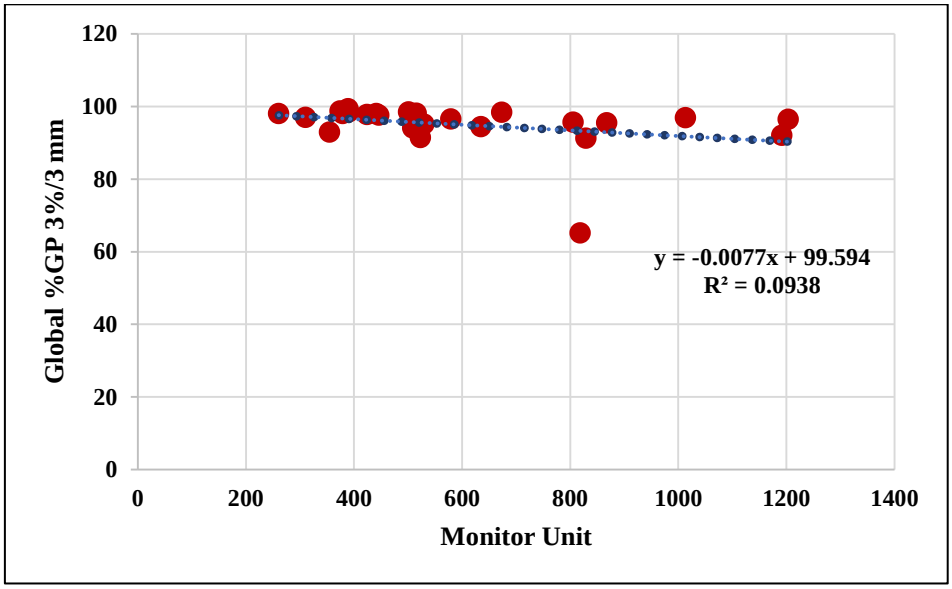

Figure 5. Linear relation between the total number of monitoring units for IMRT plans and global %GP at 3%/3mm.

4. Discussion:

The QA is widely considered to be of great importance for measuring and detecting the mismatch between the planned and delivered doses via TPS and linear acceleration, respectively. In this scenario, several guidelines were proposed to investigate specific criteria of the gamma approach to assure the agreement between the planned and delivered doses; however, no definitive tolerance was reported.

Our results revealed a higher %GP at 3%/3mm because this criterion is flexible more than 2%/2mm where the area is wider, and the accepted dose variation is higher. It should be noticed that more restriction in criteria leads to lower acceptance values such as the 2%/2mm results. The global values always show to be higher than the local because the global calculate the criteria for whole points of dose in the plan while the local %GP calculate the dose point by point.

There is a therapeutic technique for differentiating comparative concentrations. Additionally, since it entails more than just the dose itself, it will have medicinal implications. The critical point is to take into account both the spatial and dosimetric differences inherent in dosage distribution comparisons. In general, DTA denotes the interval between the two distributions' normal characteristics. Almost always, dose distributions are expressed as arrays of points, with each point

identified by a position and dose value. This study compares two distinct criteria: 3% /3 mm and 2% /2 mm. The distinction between these two standards is that they all have the same dosage differences (% DD) but have a varying distance to consensus (DTA). The DTA reflects the spacing between the points, which contributes to the dose distribution's spatial resolution. When the DTA was reduced, the resolution of the IMRT QA using the Octavius-4D phantom detector increased. These also depend on the plan resolution. The resolution of the plan that exported from the TPS to the VeriSoft software should be decreased as much as possible to increase the passing rate. More restriction leads to more QA resolution.

In this study, the total number of MU provides an indicator of the IMRT TPS efficiency. This means when a relatively high number of MU occurs, low %GP is acquired which results in low TPS efficiency. Therefore, low MU is recommended during plan optimization throughout the H&N planning. The attained results in Fig.5 are in an upright agreement with previously reported data by Shizhang Wu. et al. for global %GP at 3%/3 mm criterion and 10% threshold for 924 IMRT plans with multiple sites including the gamma value of 98.03%. Additionally, a negative linear relationship between MU and %GP was reported. The same criteria were also utilized for brain tumor using 3%/2 and 5%/1 mm TPS and %GP of 91.7% and 69%, respectively.

Furthermore, our finding also agrees with a reported study by Park et al.[13] where the pronounced research group used two types of linacs; namely, TruBeam and Trilogy. Each one employed two types of array detectors (MapCHECK2 and ArcCHECK). It was observed that both used linacs exhibited H&N plans with higher %GP in the case of 3%/3 mm as compared to 2%/2 mm. Similar findings were found in the literature which supports this study results. Continuously, it was found from the standard deviation investigation that the value obtained using any criterion is unsuitable for clinical applications. The 3%/3 mm exhibited a low gamma SD value with a threshold of 5% which agrees well with other findings obtained by Bresciani et al. [21] this, in turn, could be attributed to similar plans dose utilized.

5. Conclusion:

It can be concluded from the presented study that the dose distribution between both criteria (2%/2 and 3%/3 mm) are varied; the former demonstrated higher sensitivity as compared to the latter. Furthermore, it was noticed that the distribution profile of 2%/2 mm revealed higher sensitivity in comparison to the 3%/3 mm. The correlation between MU and %GP shows a decrease in the value of both 2%/2mm and 3%/3mm %GP as the MU number increased.

Authors' declaration:

- Conflicts of Interest: None.
- I hereby confirm that all the Figures and Tables in the manuscript are mine. Besides, the Figures and images, which are not mine, have been given the permission for re-publication attached with the manuscript.
- The author has signed an animal welfare statement.
- Ethical Clearance: The project was approved by the local ethical committee in University of Al-Nahrain and Ministry of Health, medical city numbered 32147

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التحقق من قياس الجرعات لمعدل اجتياز جاما لحالات الرأس والرقبة التي تم علاجها باستخدام أسلوب التخطيط بالعلاج الإشعاعي المعدل الشدة (IMRT)

سهام صباح عبدالله

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الخلاصة:

يجب اختبار كل خطة علاج إشعاعي معدل الشدة (IMRT) والتحقق منها قبل أي علاج للتحقق من جودتها. جهاز كشف فانتوم نوع Octavius 4D-1500 هو جهاز حديث ومؤهل لإجراء ضمان الجودة. هدفت هذه الدراسة إلى مقارنة معايير قياس الجرعات الشائعة 3٪ / 3 مم مع 2٪ / 2 مم لخطط الراس والرقبة(H&N) لتقنية IMRT. خمسة وعشرون مريضًا يعانون من ورم في الرأس والرقبة (H&N) تم علاجهم باستخدام شعاع فوتون الأشعة السينية MV6 باستخدام برنامج تخطيط العلاج موناكو 5.1 وتم ارسالها الى المعجل الخطي Elekta ثم اختبارهم لدراسة التحقق من المعالجة المسبقة باستخدام جهاز OCTAVIUS 4D-1500 . تم تقييم الفرق بين الجرعة المخططة والمقاسة باستخدام طريقة تحليل مؤشر جاما المحلي والعالمي عند عتبة 10٪. يتم تنفيذ معايير DD / DTA بنسبة 3٪ / 3 مم و 2٪ / 2 مم. يظهر فرق كبير بين جرعة النقطة المقاسة والمحسوبة لخطط العلاج. تُظهر المقارنة التي تم إجراؤها بين معدل تمرير جاما بين 2٪ / 2 مم و 3٪ / 3 مم اختلافًا كبيرًا بين المحلي والعالمي أن 2٪ / 2 مم أكثر حساسية لتغير الجرعة من 3٪ / 3 مم. تُظهر وحدة الشاشة الإجمالية (MU) علاقة خطية سالبة مع كل من المعايير وأنواع GP. أظهر ارتباط كبير بين إجمالي MU و GP العالمية عند معيار 2 ٪ / 2 مم. تظهر خاتمة الدراسة أن معيار 2٪ / 2 مم أكثر حساسية لتغيرات توزيع الجرعة من 3٪ / 3 مم. يجب أن يؤخذ العدد الإجمالي لوحدات المراقبة في الاعتبار أثناء التخطيط لأورام H&N باستخدام خطط IMRT.

الكلمات المفتاحية: معايير قياس الجرعات، العلاج الإشعاعي المعدل الشدة، وحدة المراقبة، اوكتافيوس.