RESEARCH ARTICLE

# The correlation of the modulation complexity score (MCS) with the number of segments and local gamma passing rate for the Intensity Modulated Radiation Therapy (IMRT) treatment planning delivery

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## Abstract

**Objective:** To compare the modulation complexity scores across treatment sites, and to examine their connection with monitor unit, segment number and global and local gamma passing percentage.

**Method:** The cross-sectional study was conducted at the Baghdad Centre for Radiation Therapy and Nuclear Medicine, Baghdad Medical City, Baghdad, Iraq, from May 2021 to February 2022. Included were 34 patients, with the age range between 20 – 50 years, subjected to intensity-modulated radiation therapy for head and neck tumours in group A or pelvic tumours in group B. Treatment planning was done using Monaco 5.1, and radiotherapy was done using Synergy linear accelerator. Modulation complexity scores were calculated using MATLAB 2019a. Data was analysed using SPSS 24.

**Results:** Of the 34 patients, 22(64.7%) were in group A; 12(54.5%) males and 10(45.5%) females. There were 12(35.3%) patients in group B; 8(66.7%) females and 4(33.3%) males. The number of segments was greater in group B than group A. A modest positive linear association was seen in group A, demonstrating that an increase in segment numbers resulted in a rise in modulation complexity score (R2=0.0244). Group B tumours had inverse negative linear correlation (R2=0.0189). As the complexity of plans increased in group A, local gamma passing percentage decreased (R2=0.0452). Group B showed a slight negative connection with modulation complexity score (R2=0.0622).

**Conclusion:** The modulation complexity score may be used to provide a simple prediction for pre-treatment verification, and it may also serve as a simple quality assurance tool for intensity-modulated radiation therapy plans.

**Key Words:** Monaco, Nuclear, Pelvic, Head and Neck

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## Introduction

Radiotherapy is a treatment with ionizing radiation that can destroy the carcinogenic cells' deoxyribonucleic acid (DNA). In contrast, non-cancer cells are capable of repairing the damaged DNA. The enhanced reproductive status in which cancerous cells are present can reduce their ability to replicate small amounts of DNA damage. Radiation therapy (RT) aims at focussing the radiation to ensure that the targetted area receives sufficient dose to kill the cancer cells and yet maintain a minimum degree of safety in the anatomical structures around them[1–3].

A linear accelerator treats deep and superficial tumours using ionizing radiation (X-ray photons or electrons)[4,5]. The treatment planning system (TPS) is a key element of external therapy with beam radiation. TPS is used to develop beam plans, energy field sizes, fluence patterns and modifications that provide the best dosage delivery for treatment and reduce the dose to healthy tissues[6].

Intensity-modulated radiation treatment (IMRT) employs standardised beam intensities to maximise the dosage delivered to the tumour while minimising the risk of normal tissue complications[7]. The modulation has been designed to optimise the efficacy of a treatment plan, thus reducing the dosage to organs at-risk (OARs), which are normal critical structures, by providing the expected prescribed dose to the target. However, this optimisation process may lead to excessively modulated areas that increase the beam time and are much more difficult to deliver[8,9]. IMRT step-and-shoot (SS) approach, also known as stop-and-shoot or segmental, is a way of delivering IMRT with fixed beams that are based on multileaf collimator (MLC). In SS-IMRT, the patient's treatment is done by many fields (beams). The gantry is not rotating through irradiation. Therefore, any collimator is a subfield or segment by a fractional weighted summation from all subfields, and the desired intensity pattern is produced. Before treating the patient, there is a need to ensure that the prescribed dose gets delivered to the patient. So,

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quality assurance (QA) is required to ensure consistency of the medical prescription and safe fulfilment of that prescription[10,11]. A cylindrical four-dimensional (4D) phantom device, OCTAVIUS (PTW, Freiburg, Germany) used a 1500 detector to evaluate the QA process[12,13]. It used as a tool to show the agreement between the measured and calculated dose, called the gamma (γ) index. The index is one of the most common measurements used for testing complex RT distribution, and volumetric modulated arc radiation therapy (VMAT) [14,15]. OCTAVIUS 4D detector used to examine the amount of distributed dose acquired from the TPS as a reference dose compatibility with the dose distribution acquired from the phantom detector (measured dose) during a QA procedure[16,17]. It primarily uses two parameters: dosage differential (D) in percentage, and distance to the agreement (DTA) in millimetres (DTA). These two parameters are used to normalise their respective tolerance values to the dose and distance metrics[14].

The modulation complexity score (MCS) is an integration of two contributions to the complexity of segments in the plan. The MCS uses a fixed 0-1 range, and, unlike the other indicators of complexity, is defined to increase complexity by lowering the MCS value. When MCS value is 1, it does not mean a modulation, and the mean MCS value for a treatment site always decreases with greater complexity [18].

The current study was planned to compare the MCSs across treatment sites, and to examine their connection with monitor unit (MU), segment number and global and local gamma passing percentage (%GP).

## Materials and Methods

The cross-sectional study was conducted at the Baghdad Centre for Radiation Therapy and Nuclear Medicine, Baghdad Medical City, Baghdad, Iraq, from May 2021 to February 2022. Approval was obtained from the ethics review committee of the College of Medicine, Mustansiriyah University, and the College of Medicine Al-Nahrain University, Iraq. The sample was raised using convenience sampling technique. Those included were patients between 20 and 50 years, undergoing IMRT for head and neck (H&N) tumours in group A and pelvic tumours in group B. Informed consent was obtained from all the participants, and those not willing to volunteer were excluded.

Treatment planning was done using Monaco 5.1 manufactured by Elekta, Sweden. The patients were irradiated with 6MV or 10MV X-ray beam using Synergy linear accelerator (Elekta, Sweden). Treatment planning data was applied using Octavius 4D detector (PTW, Freiburg, Germany) equipped with an engine that read the inclinometer's output and could spin in lockstep with the portal of medical linear accelerator (LINAC) (Elekta, Sweden).. Calculations of the gamma index were done using Verisoft 7.1, which is used to create and analyse IMRT plans. The percentage of gamma plan % GP criteria was used to determine the absorbed dose distribution (DD/DTA) and it was 3%/3mm with a level of 5%. The MCS was used to evaluate the precision of pre-treatment IMRT planning. The information of MLC and radiation beam data was recorded using the MATLAB 2019a programme to use its code for calculating the MCS for each beam, and then for all the plans.

Data was analysed using SPSS 24. The significance of the difference between mean quantitative values was examined using the students' test or the unpaired test, as appropriate. Spearman Rho correlation test was also used when needed. A scatter distribution curve for correlation was also employed. $P<0.05$was considered statistically significant.

## Results

Of the 34 patients, 22(64.7%) were in group A; 12(54.5%) males and 10(45.5%) females. There were 12(35.3%) patients in group B; 8(66.7%) females and 4(33.3%) males. The number of segments was greater in group B than group A (Table 1).

**Table-1:** The relationship of MCS with the number of segments and rhe local gamma passing percentage (%GP).

| **a. the No. of Segments**<br>**Site of The Treatment** | **MCS** | **No. of Segments** |
|---|---|---|
| H&N | 0.48 ± 0.12 | 51.21±30.86 |
| Pelvis | 0.65 ± 0.18 | 52.84 ±16.6 |
| All cases | 0.55±0.16 | 51.83±26.19 |
| **b. MCS with The Local %GP**<br>**Site of The Treatment** | **MCS** | **Local %GP** |
| H&N | 0.48 ± 0.12 | 89.634 ± 8.524 |
| Pelvis | 0.65 ± 0.18 | 88.954 ±3.877 |
| All cases | 0.55±0.16 | 89.401 ± 7.210 |

H&N: Head and neck, MCS: Modulation complexity score.

A modest positive linear association was seen in group A, demonstrating that an increase in segment numbers resulted in a rise in MCS (R2=0.0244). Group B tumours had inverse negative linear correlation (R2=0.0189). (Figure 1).

As the complexity of plans increased in group A, local %GP decreased (R2=0.0452), while group B showed a weak correlation (R2=0.0622) (Figure 2).

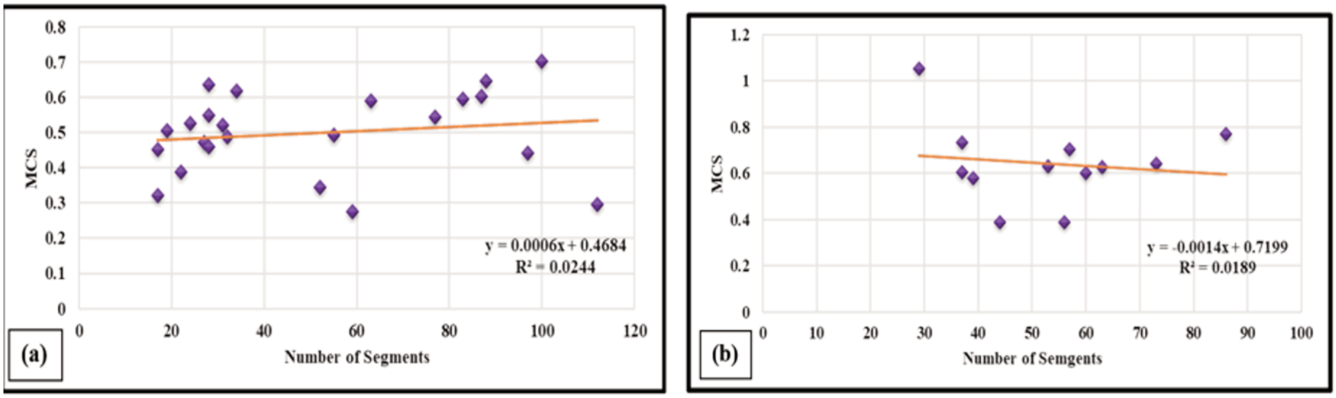

**Figure-1:** The relationship between modulation complexity score (MCS) and the number of segments in the head and neck (H&N) (a) and pelvis (b) groups.

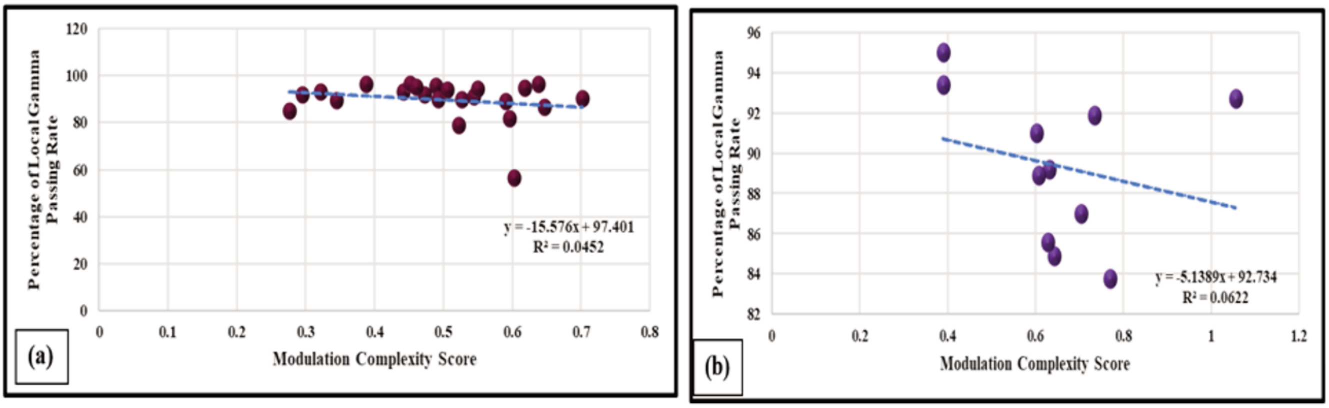

**Figure-2:** The relationship between the modulation complexity score (MCS) and local gamma passing percentage (%GP) in the head and neck (H&N) and pelvis (b) groups.

## Discussion

The current study, to our knowledge, is the first to correlate the MCS value with local %GP for IMRT plans. The study showed that the number of segments for pelvis plans was higher than that of the H&N. Also, there was a limited or no correlation between the MCS and the number of segments for H&N and pelvis plans. So, it is recommended to lower the number of segments when making IMRT plans for the pelvis to make it simpler. A study[19] found a higher number of segments in H&N than the pelvis with IMRT plans, and the plan with a lower mean value of complexity had a higher number of segments. McNiven et al.[19] agreed with the current results as they found no or limited correlation between the pelvis and H&N plans, with fewer segments for the pelvis.

Park et al.[21] studied the correlation between MCS values and local %GP with VMAT and noted a significant correlation between MCS and local %GP with 3%/3mm criteria.

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

## Conclusion

The MCS may be used to provide a simple prediction for pre-treatment verification, and it may also serve as a simple quality assurance tool for IMRT plans.

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## References

1. In: Alves CJS, Pardalos PM, Vicente LN, eds. Optimization in medicine, 1st ed. Berlin, Germany: Springer, 2007; pp 1-195.
2. Alabedi HH, Al Musawi MS, Ali NM. Dosimetric effects and impacts caused by a carbon fiber table and its accessories in a linear accelerator. J Contemp Med Sci 2023;9:206-10. Doi:

10.22317/jcms.v9i3.1355.
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. 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 2021;18:414-20. DOI: 10.22038/IJMP.2020.49211.1791.
6. Smilowitz JB, Das IJ, Feygelman V, Fraass BA, Kry SF, Marshall IR, et al. AAPM Medical Physics Practice Guideline Task Group. AAPM Medical Physics Practice Guideline 5.a.: Commissioning and QA of Treatment Planning Dose Calculations - Megavoltage Photon and Electron Beams. J Appl Clin Med Phys 2015;16:14–34. doi: 10.1120/jacmp.v16i5.5768.
7. Sandilos P, Angelopoulos A, Baras P, Dardoufas K, Karaiskos P, Kipouros P, et al. Dose verification in clinical IMRT prostate incidents. Int J Radiat Oncol Biol Phys 2004;59:1540-7. doi: 10.1016/j.ijrobp.2004.04.029.
8. Jubbier ON, Abdullah SS, Alabedi HH, Alazawy NM, AlMusawi MJ. The Effect of Modulation Complexity Score (MCS) on the IMRT Treatment Planning Delivery Accuracy. J Phys Conf Ser 2021;1829:012017. DOI: 10.1088/1742-6596/1829/1/012017.
9. Abdulbaqi A, Abdullah SS, Alabed HH, Alazawy NM, Hamzaalabed H, Al-Musawi MJ, et al. The Correlation of Total MU Number and Percentage Dosimetric Error in Step and Shoot IMRT with Gamma Passing Rate Using OCTAVIUS 4D-1500 Detector Phantom. Ann Trop Med Public Health 2020;23. DOI: 10.36295/ASRO.2020.232126.
10. Ehrgott M, Hamacher HW, Nussbaum M. Decomposition of matrices and static multileaf collimators: a survey. In: Optimization in medicine. Berlin, Germany: Springer, 2008; pp 5–46.
11. Smilowitz JB, Das IJ, Feygelman V, Fraass BA, Kry SF, Marshall IR, et al. AAPM Medical Physics Practice Guideline 5.a.: Commissioning and QA of Treatment Planning Dose Calculations - Megavoltage Photon and Electron Beams. J Appl Clin Med Phys 2015;16:14–34. doi: 10.1120/jacmp.v16i5.5768.
12. Anders M. Clinical 3D dosimetry in modern radiation therapy. Acta Onco 2018;57:1421. Doi: 10.1080/0284186X.2018.1478668.
13. 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.
14. Low DA, Harms WB, Mutic S, Purdy JA. A technique for the quantitative evaluation of dose distributions. Med Phys 1998;25:656-61. doi: 10.1118/1.598248.
15. Hussein M, Clark CH, Nisbet A. Challenges in calculation of the gamma index in radiotherapy-Towards good practice. Phys Med 2017;36:1-11. doi: 10.1016/j.ejmp.2017.03.001.
16. Hussien M. Evaluation of detector array technology for the verification of advanced intensity-modulated radiotherapy. [Online] 2015 [Cited 2024 August 15]. Available from URL: https://ui.adsabs.harvard.edu/abs/2015PhDT.......292H/abstract
17. Ezzell GA, Galvin JM, Low D, Palta JR, Rosen I, Sharpe MB, et al. Guidance document on delivery, treatment planning, and clinical implementation of IMRT: report of the IMRT Subcommittee of the AAPM Radiation Therapy Committee. Med Phys 2003;30:2089-115. Doi: 10.1118/1.1591194.
18. Masi L, Doro R, Favuzza V, Cipressi S, Livi L. Impact of plan parameters on the dosimetric accuracy of volumetric modulated arc therapy. Med Phys 2013;40:071718. doi: 10.1118/1.4810969.
19. Svensson E, Bäck A, Hauer AK. Evaluation of complexity and deliverability of IMRT-treatment plans. Göteborg, Sweden: The Sahlgrenska Academy; 2011.
20. McNiven AL, Sharpe MB, Purdie TG. A new metric for assessing IMRT modulation complexity and plan deliverability. Med Phys 2010;37:505-15. doi: 10.1118/1.3276775.
21. Park SY, Kim JI, Chun M, Ahn H, Park JM. Assessment of the modulation degrees of intensity-modulated radiation therapy plans. Radiat Oncol 2018;13:1–8. DOI: 10.1186/s13014-018-1193-9.