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Keywords

plans, qa, dosimetric, routine, arccheck, score, pass, gamma, benchmarking, vmat

Disciplines

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Benchmarking the gamma pass score using ArcCHECK for routine dosimetric QA of VMAT plans

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Abstract. A minimum expected gamma (γ) pass rate for VMAT plan verification using ArcCHECK was established based on the RTTQA, TG119 test cases and 10 clinical plans with varying levels of complexity. The impact of the ‘Measurement Uncertainty’ parameter as available in the ArcCHECK software on γ pass rate was studied for both global and local γ analysis. Our results show that excluding measurement uncertainty adds tighter tolerance in local γ comparison. From the verification of our benchmark cases we established minimum expected γ pass rates of 85% and 88% for 2%/2mm global and 3%/3mm local tolerance criteria.

1. Introduction

Volumetric Modulated Arc Therapy (VMAT) has been shown to enable more efficient treatment delivery compared to conventional static gantry based Intensity Modulated Radiation Therapy (IMRT) delivery methods [1, 2]. The efficiency of VMAT comes at the cost of added complexity in the treatment planning and delivery stages. The complex nature of VMAT necessitates comprehensive three dimensional (3D) dosimetric validation of the plans to ensure dosimetric accuracy of planning and delivery [3]. Recently many electronic dosimetric systems have been introduced commercially that provide semi-3D or 3D dose information of the delivered treatment plans [4, 5].

ArcCHECK (Sun Nuclear Corporation (SNC), USA) is one such system which uses diode detectors arranged in a helical array in a perspex cylindrical phantom. In routine clinical practice the cumulative dose matrix measured by ArcCHECK is compared with the TPS calculated dose in similar geometry [4] using gamma analysis [6]. In SNC software in addition to the user defined tolerance criteria an additional optional parameter called ‘Measurement Uncertainty’ (ϵ) is provided. The manufacturer defines this parameter as follows: “Measurement uncertainties include differences between the absolute calibration of the device and the standard dose value due to setup error, temperature change, accelerator output fluctuation, array calibration accuracy, and electronic measurement precision. The measurement uncertainty (ϵ) is added to the percentage acceptance criterion defined by the user and is typically smaller than 1% for the relative comparison and close to 1% for the absolute comparison”



[7]. This parameter increases the dose tolerance criteria but does not impact on the distance tolerance criteria. The published γ pass rates for VMAT plans using ArcCHECK don't clearly specify whether this parameter is included in the analysis or not [2].

In this work we study the impact of this parameter on the local (L) and global (G) γ analysis of the ArcCHECK measured and TPS calculated dose matrices. Also we establish a benchmark pass rate with different types and level of tolerance criteria to ensure the accuracy of VMAT plans appropriate for our centre using the ArcCHECK dosimetric system.

2. Materials and Methods

The Pinnacle, v 9.2, (Philips Ltd, USA) Treatment Planning System (TPS) was used to generate VMAT plans using a 6 MV photon beam model for an Elekta Synergy (Elekta Ltd, Crawley, UK) Linear Accelerator (linac). Dose calculations for all plans in the study were performed using the adaptive convolution dose calculation algorithm. The Synergy accelerator used in this study was equipped with an Multi Leaf Collimator (MLCi) head and Integrity v1.1 linac control software.

2.1. Benchmark VMAT plans

Two sets of plans were considered to benchmark the dosimetric accuracy of VMAT plans. The first set included recommended test cases from the UK Radiotherapy Trial Quality Assurance (RTTQA) group and AAPM Task Group 119 (TG119). This includes the 3D treatment planning system (3DTPS) test cases from RTTQA and Mock Prostate, Mock Head and Neck, Multi Target, C shape-easy and C shape-hard from TG119 [8, 9]. In the second group 10 clinical cases with varying levels of complexity in target volume and dose objectives were selected retrospectively from clinical cases. This included 5 head and neck, 3 prostate and 2 pelvic nodes cases. The VMAT plans were generated with single full arc for simple cases and double full arcs for complex cases. RTTQA and TG119 recommended dose objectives were used for the test cases and for clinical cases the dose objectives prescribed as per RTOG guidelines and ICRU83 prescription methodology was used as the achievable aim [10].

2.2. Plan verification and analysis

The dosimetric accuracy of the generated plans was verified by the following three measurements: 1. point dose measurements in high, medium and low dose regions using a CC13 ion chamber in a CIRS phantom, 2. Coronal plane dose distribution verification using EBT3 gafchromic film placed in a solid water phantom, and 3. Cumulative dose measurement using the ArcCHECK dosimetric system.

The coronal film measurements were compared with the TPS calculated dose matrices using global γ analysis with 3%/3mm (3%G/3mm) tolerance criteria in RIT film dosimetry software. The ArcCHECK measured and TPS calculated dose matrices were compared using global and local γ analysis with 2%/2mm and 3%/3mm (2%G/2mm, 3%G/3mm and 2%L/2mm, 3%L/3mm) with and without the measurement uncertainty parameter included. In order to assess the impact of the measurement uncertainty (e) parameter on the tolerance criteria analysis was also performed with 1%G/2mm, 2%G/3mm, 1%L/2mm and 2%L/3mm with the uncertainty parameter. All γ analysis was performed with a high dose threshold of 10% and gamma tolerance of 1.

3. Results and Discussion

The generated VMAT plans successfully achieved the dose objectives recommended by the RTTQA group and TG119 for all test cases except the C shape hard case. As the aim of the C-shape hard case is to test a system that is being pushed very hard this was not unexpected.

The point dose agreement in the CIRS phantom at high, medium and low dose regions of all studied plans resulted in a mean (1σ) percentage difference of -0.5 (1.3)%, 0.5 (1.6)% and -0.6 (3.4) % respectively. The coronal plane dose verification using film resulted in a mean (1σ) γ pass rate of 96.6 (2.7)%.

Figure 1 shows the local and global γ pass rates with 2%/2mm and 3%/3mm pass rates for studied VMAT plans. Figure 2 a, b and c show the gamma analysis results with 3%G/3mm with ' e ',

3%G/3mm without 'e' and 2%G/3mm with 'e' for 3DTPS test case. Figures 3 a, b and c show similar results with local gamma analysis. In the figures the red and blue points show the failed points with high and low dose respectively. Table 1 shows the mean (1σ) γ pass rates with local and global γ analysis with and without measurement uncertainty in the analysis.

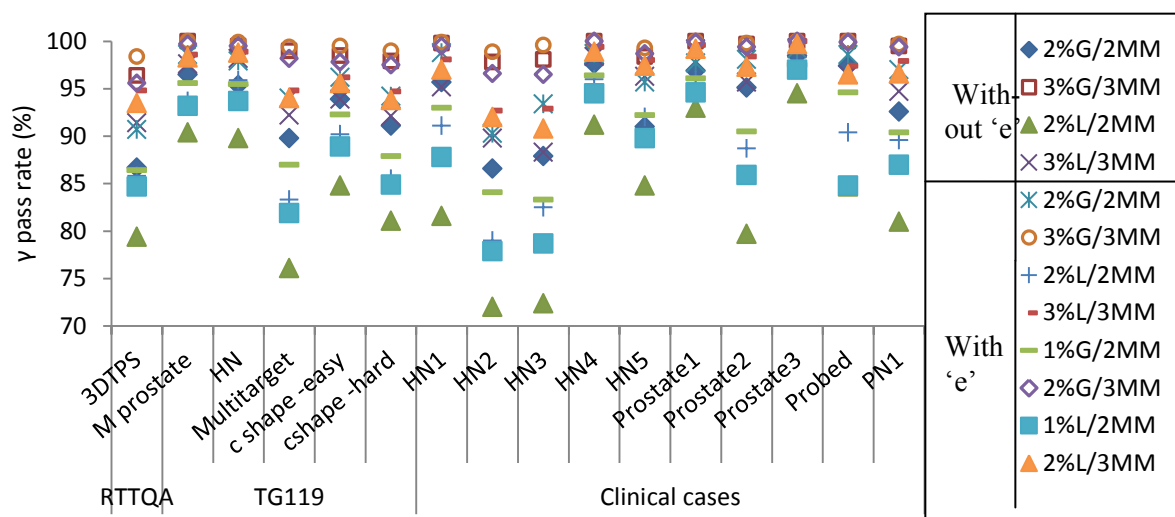


Figure1. Gamma pass rate with different tolerance criteria for studied VMAT plans using ArcCHECK.

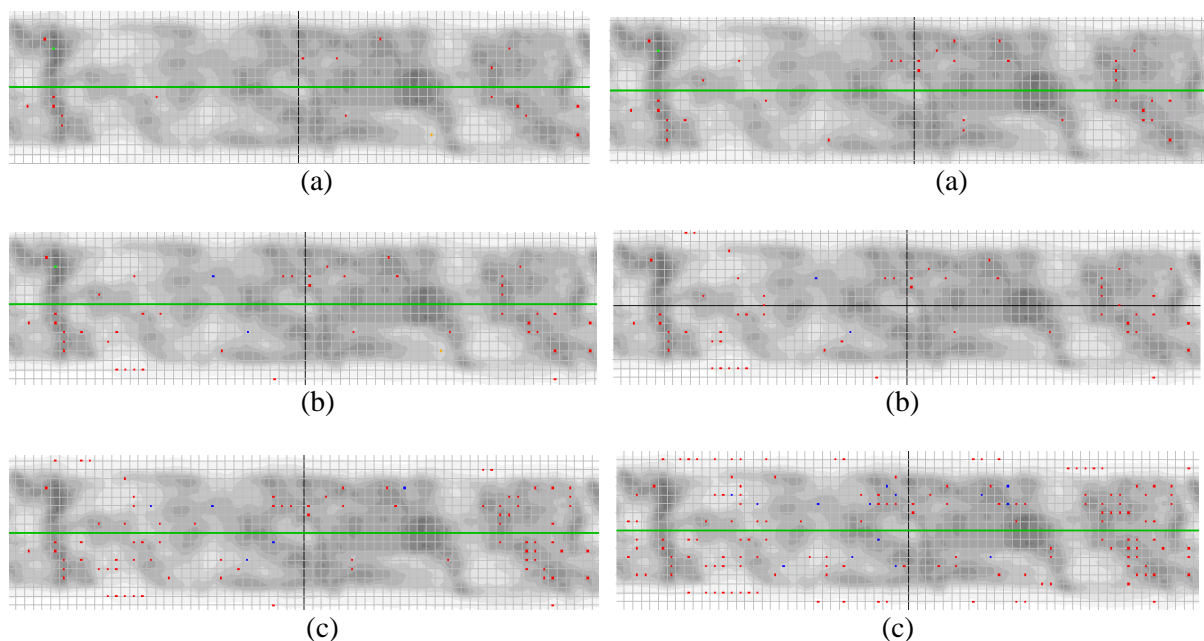


Figure 2. γ pass results for 3DTPS test plan with (a) 3%G/3mm with 'e', (b) 3%G/3mm without 'e' and (c) 2%G/3mm without 'e' tolerance criteria. Red and blue points show failed detector points with high (red) and low (blue) dose measurements.

Figure3. γ pass results for 3DTPS test plan with (a) 3%L/3mm with 'e', (b) 3%L/3mm without 'e' and (c) 2%L/3mm without 'e' tolerance criteria. Red and blue points show failed detector points with high and low dose measurements.

Measurement uncertainty	Tolerance criteria			
	2%G/2mm	3%G/3mm	2%L/2mm	3%L/3mm
Included	96.1(3.0)	99.6(0.5)	89.8(5.6)	97.0(2.4)
Not included	93.1(4.6)	99.0(1.1)	83.7(7.1)	94.9(3.5)
Included	1%G/2mm	2%G/3mm	1%L/2mm	2%L/3mm
	91.5(4.7)	98.6(1.5)	87.9(5.9)	96.2(2.8)

Table 1. Mean (1σ) gamma pass rate of studied VMAT plans with different tolerance criteria.

In general including measurement uncertainty results in higher pass rates both in global and local γ comparisons due to the additional dose tolerance added to the user defined dose tolerance. The manufacturer states that the measurement uncertainty value is approximately 1% for the γ comparison in absolute dose mode. From our results the gamma pass rate for 2%/2mm and 3%/3mm tolerance criteria without measurement uncertainty included was not equal to the 1%/2mm and 2%/3mm criteria with measurement uncertainty (table 1, figures 1, 2 and 3). Also not including the measurement uncertainty in the global tolerance resulted in tighter criteria (reduced pass rate) whereas in local tolerance it resulted in more relaxed tolerance criteria (increased pass rate) (table 1).

While there is a lack of evidence between the correlation of acceptable gamma pass rate and clinical significance, 95% pixels passing the global γ analysis with 3%/3mm tolerance criteria (3%G/3mm) is considered to be widely acceptable in clinical practice. Many of the IMRT and VMAT credentialing bodies also follow this. Nelms *et al* show that 2%L/2mm has been shown to more closely reflect the clinically significant errors in treatment plans compared to the more generous 3%G/3mm criteria [11]. Similarly to the ArcCHECK software, Nelms *et al* also included measurement uncertainty in the analysis. Our results show that excluding measurement uncertainty adds a tighter tolerance in local γ comparison. From the verification of our benchmark cases we set a γ pass rate of mean- 2σ as our minimum expected pass rate for clinical VMAT plans. Based on this we set minimum pass rate of 85% and 88% for 2%G/2mm and 3%L/3mm tolerance criteria respectively noting that higher pass rates are expected for simple plans.

4. Conclusion

Exclusion of the measurement uncertainty parameter results in a tighter tolerance in local γ comparison of the ArcCHECK dose verification. Based on the verification of our benchmark plans we set γ pass rates of 85% and 88% as minimum expected pass rates for our clinical VMAT plans for 2%G/2mm and 3%L/3mm tolerance criteria.

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