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Evaluation of 3D Gamma index calculation implemented in two commercial dosimetry systems

Aitang Xing
Liverpool and Macarthur Cancer Therapy Centres

Sankar Arumugam
Liverpool and Macarthur Cancer Therapy Centres

Shrikant Deshpande
University of Wollongong, sd110@uowmail.edu.au

Armia George
Liverpool and Macarthur Cancer Therapy Centres

Philip J. Vial
Liverpool and Macarthur Cancer Therapy Centres

See next page for additional authors

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Keywords

index, gamma, 3d, evaluation, dosimetry, calculation, systems, implemented, two, commercial

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Authors

Aitang Xing, Sankar Arumugam, Shrikant Deshpande, Armia George, Philip J. Vial, Lois C. Holloway, and Gary Goozee

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Aitang Xing[1], Sankar Arumugam[1], Shrikant Deshpande[1], Armia George[1], Philip Vial[1], Lois Holloway[1,2,3] and Gary Goozee[1]

[1]Liverpool and Macarthur cancer therapy centres and Ingham Institute, Liverpool Hospital, New South Wales, Australia

[2]Institute of Medical Physics, School of Physics, University of Sydney, New South Wales, Australia

[3]Centre for Medical Radiation Physics, University of Wollongong, Wollongong, New South Wales, Australia

E-mail: aitang.xing@sswahs.nsw.gov.au

Abstract. 3D Gamma index is one of the metrics which have been widely used for clinical routine patient specific quality assurance for IMRT, Tomotherapy and VMAT. The algorithms for calculating the 3D Gamma index using global and local methods implemented in two software tools: PTW- VeriSoft® as a part of OCTIVIUS 4D dosimeter systems and 3DVH[TM] from Sun Nuclear were assessed. The Gamma index calculated by the two systems was compared with manual calculated for one data set. The Gamma pass rate calculated by the two systems was compared using 3%/3mm, 2%/2mm, 3%/2mm and 2%/3mm for two additional data sets. The Gamma indexes calculated by the two systems were accurate, but Gamma pass rates calculated by the two software tools for same data set with the same dose threshold were different due to the different interpolation of raw dose data by the two systems and different implementation of Gamma index calculation and other modules in the two software tools. The mean difference was -1.3%±3.38 (1SD) with a maximum difference of 11.7%.

1. Introduction

With increasing complexity of radiotherapy delivery from 3D-CRT to IMRT, VMAT and Tomotherapy, patient-specific quality assurance (QA) for patient plans is gradually moving away from verifying the planar dose and the dose at one point to verifying the dose distribution in three dimensional (3D) space [1]. The basic task for patient-specific QA based on 3D dosimetry is to compare two data sets of points of known spatial position and an associated absorbed dose value. One data set is usually 3D dose calculated in patient or phantom geometry by the treatment planning system (TPS) and another is the measured dose in the phantom or reconstructed dose in patient from 2D detector measured dose or fluence. To quantify the agreement between these two data sets, the Gamma index proposed by Low [2] has been widely used for clinical routine work and research.

The algorithm to calculate the 3D Gamma index was implemented in two software tools: VeriSoft® from PWT as an integrated component of the OCTIVIUS 4D dosimeter system [3] and 3DVH[TM] software from Sun Nuclear Corporation, Melbourne, and FL. [4]. The purpose of this paper is to evaluate the accuracy of the 3D Gamma index calculation engine implemented independently in these systems by two different vendors.

2. Materials and Methods

2.1. PTW-VeriSoft and 3DVH^{TM}

VeriSoft$^®$ (version 5.1) is the patient plan verification software for PTW OCTIVIUS 4D detector [3], whereas 3DVH^{TM} (version 2.21.28208) is a software tool that is able to estimate the 3D dose distribution in the patient using the measured dose in the phantom from ArcCHECK$^®$, MapCHECK $^®$ or EPIDose^{TM} [4]. Both of them are able to load DICOM-RT dose files and calculate a 3D Gamma map using their built-in 3D Gamma calculation engine. Depending on the normalization value of the dose difference between measured and calculated dose points, there are two schemes for calculating Gamma index: local calculation method and global calculation method [4]. In the local normalized method the TPS calculated dose corresponding to the point measured is used to determine the acceptable dose difference criteria when determining percentage error. In the global calculation method, the acceptable dose difference criteria use the maximum dose found in the patient plan dose.

2.2. Preparation of the Data set

To compare the accuracy of the 3D Gamma calculators in VeriSoft$^®$ and 3DVH^{TM}, three reference/evaluation pairs were used for this study (summarized in Table 1). All data sets were in the standard DICOM RT dose format. For Sample A, Reference and Evaluated dose are dose cubes with 127 slices, each of which is a 144-by-201 matrix. The voxel resolution along X, Y and Z (slice direction) is 1mm for reference and the Evaluated 3D dose. The dose at the point (0, 0, 0) in reference 3D dose is 200cGy and 0cGy at all other points. In evaluated 3D dose set, the doses are 195cGy at points (1,1,1) and (-1,-1,-1) , 198cGy at points (-2,2,-2) and (2,-2,-2) and 0cGy at all other points.

Table 1. A summary of the datasets compared in this study.

Data set name	Reference 3D dose	Evaluated 3D dose	Case study
Sample A	Reference dose	Evaluated dose	
Sample B	Original plan dose	Plan dose with 1mm MLC errors	VMAT-Prostate
Sample C	Original plan dose	Plan dose with 3mm MLC errors	VMAT-Prostate
Sample D	Original plan dose	Plan dose with 3mm MLC errors	IMRT-prostate

The original plan dose in Samples B and C were exported as DICOM-RT dose files from two clinical patient plans. These two plans were generated in the Pinnacle treatment planning system (Philips, Version 9.6). IMRT plan was a typical 9 beam plan and contains 95 control points. The VMAT plan was a single arc plan and has 89 control points. The calculation grid was 2.5 mm for the X, Y and Z direction. A 1 mm systematic error was introduced into the multileaf collimator (MLC) position of each control point for the VMAT plan while the remaining plan parameters were unchanged. The plan with MLC errors was recalculated and DICOM RT dose was exported and used as the evaluated 3D dose. For the IMRT plan, 3 mm MLC errors were introduced instead of 1 mm errors to simulate a large dose variation across the whole dose volume. Here use of the TPS-calculated dose distribution as the evaluated dose cube instead of the measured dose cubes from different detectors was used to avoid uncertainties that may be introduced due to phantom setup, machine output variation or the resolution of detector array.

2.3. Calculation of 3D Gamma map in VeriSoft$^®$ and 3DVH^{TM}

The user interface for the 3D dose map calculation in VeriSoft$^®$ is different from 3DVH^{TM}'s, but they both provide options for users to choose the Gamma calculation method and change the Gamma criteria such as distance to agreement (DTA), dose difference and dose threshold. The search distance cannot be changed by the user in either software. It was noticed that the DICOM-RT dose loaded into 3DVH^{TM} was automatically interpolated into 1mm resolution along three directions. VeriSoft$^®$ interpolated the DICOM-RT dose into 1mm resolution but kept the slice direction resolution unchanged. The end-user has no control or option on interpolation. The 3D Gamma indices were calculated for the whole dose volume for the three data sets using both software tools. The Gamma

pass rates were calculated and compared using global and local methods with Gamma criteria of 3%/3mm, 2%/2mm, 3%/2mm, and 2%/3 mm, respectively.

3. Results and Discussion

For sample A, the Gamma index at point (0,0,0) can be manually calculated. Within 3mm search distance around this point and using 3 % dose criteria, the following four values can be calculated: $\sqrt{(2/6)^2 + (2/3)^2} = 0.7454$, $\sqrt{(200/6)^2 + (2/3)^2} = 33.34$, $\sqrt{(5/6)^2 + (\square\square\square(3)/3)^2} = 1.0138$ and $\sqrt{(200/6)^2 + (1/3)^2} = 33.34$. The Gamma value at this point is 0.7454 and $\square = \sqrt{(0/6)^2 + (1/3)^2} = 0.3333$ at all other points. Table 2 also listed the Gamma indices calculated using the two software tools. The 3DVH calculated Gamma index was closer to the manually calculated value than the VeriSoft calculated value at point (0,0,0). At other points, both VeriSoft and 3DVH give the same values as the manually calculated. The difference is negligible for both software options due to the uncertainty in the numerical calculation.

Table 2. Comparison of 3D Gamma index calculated by VeriSoft, 3DVH and manually for Sample A.

Software	VeriSoft	3DVH	Manual
Gamma index	0.746	0.745	0.7454

Tables 3-5 presents the Gamma pass rate over the 3D dose volume for sample B, C and D using the global and local calculation methods. The dose threshold of 10% of maximum dose in reference dose cube was used. The mean Gamma pass rate difference calculated by two software tools was -1.3%±3.38 (1SD) with a maximum difference of 11.7%. The Gamma pass rate calculated by the two software options showed the same trend when the Gamma criteria changed from 3mm/3% to 2mm/2% or from global calculation method to local calculation method. In both situations, the Gamma pass rate decreased, which agrees with observation by Brescian et al [5]. As expected, the Gamma pass rates calculated by two systems also decreased for cases with larger MLC errors due to the larger dose difference and distance to agreement.

Table 3. Comparison of 3D Gamma pass rates for Sample B using global and local calculation.

Gamma Criteria	3%/3mm		2%/2mm		3%/2mm		2%/3mm	
	Global	Local	Global	Local	Global	Local	Global	Local
3DVH (%)	99.7	94.7	96	72.8	99.3	79.6	98.2	91
VeriSoft (%)	99.9	97.9	98.6	80.3	99.9	91.3	99.9	93.8
Difference (%)	-0.2	-3.2	-2.6	-7.5	-0.6	-11.7	-1.7	-2.8

Table 4. Comparison of 3D Gamma pass rates for Sample C using global and local calculation.

Gamma Criteria	3%/3mm		2%/2mm		3%/2mm		2%/3mm	
	Global	Local	Global	Local	Global	Local	Global	Local
3DVH (%)	94.1	90.4	91.6	78.2	93.2	82.3	93.4	88.9
VeriSoft (%)	93.4	89.4	89.19	77.2	92.1	79.19	92.1	88.9
Difference (%)	0.7	1	2.41	1	1.1	3.11	1.3	0

Table 5. Comparison of 3D Gamma pass rates for Sample D using the global and local calculation.

Gamma Criteria	3%/3mm		2%/2mm		3%/2mm		2%/3mm	
	Global	Local	Global	Local	Global	Local	Global	Local
3DVH (%)	60.3	52.1	48.2	40.6	55.6	42.5	55.4	51
VeriSoft (%)	64.7	52.1	51.6	38.9	59.8	42.6	58.2	49.4
Difference (%)	-4.4	0	-3.4	1.7	-4.2	-0.1	-2.8	1.6

Although the results from simple dataset A indicated that the basic Gamma index calculation is accurate in both software tools, the Gamma pass rates for clinical dose set varied depending not only on Gamma criteria, Gamma calculation method but also the data set. For example, a larger difference

as 11.7% was observed for data set B using 3%/2mm and local method. The reported Gamma pass rate difference by 3DVH^{TM} and VeriSoft$^{\circledR}$ is contributed to the combination of several factors: (1) Interpolation of original dose into fine resolution before Gamma calculation; (2) DTA search algorithm implementation for both local and global calculation method; (3) reporting of Gamma pass rate. Both software tools are black boxes to the end user as the user does not know what interpolation method was used, which specific DTA search algorithm was adopted and the total number of evaluated voxel for same threshold. For comparison studies or routine patient-specific quality assurance using different dosimeter systems, it is important to be aware that the Gamma pass rate can be different due to different software implementation.

4. Conclusion
The Gamma pass rates reported by two different software systems for the same data set may differ by a few percent due to the different implementation by different vendors.

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