Three dimensional dose verification of VMAT plans using the Octavius 4D dosimetric system

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Abstract. The Octavius 4D dosimetric system generates a 3D dose matrix based on a measured planar dose and user supplied Percentage Depth Dose (PDD) data. The accuracy of 3D dose matrices reconstructed by the Octavius 4D dosimetric system was systematically studied for an open static field, an open arc field and clinical VMAT plans. The Octavius reconstructed 3D dose matrices were compared with the Treatment Planning System (TPS) calculated 3D dose matrices using 3D gamma (γ) analysis with 2%/2mm and 3%/3mm tolerance criteria. The larger detector size in the 2D detector array of the Octavius system resulted in failed voxels in the high dose gradient regions. For the open arc fields mean (1σ) γ pass rates of 84.5(8.9) % and 94.2(4.5) % were observed with 2%/2mm and 3%/3mm tolerance criteria respectively and for clinical VMAT plans mean (1σ) γ pass rates of 86.8(3.5) % and 96.7(1.4) % were observed.

1. Introduction

Modern radiotherapy techniques are highly complex and Volumetric Modulated Arc Therapy (VMAT) follows the same trend [1, 2]. Three dimensional dose verification of VMAT plans is recommended to ensure the dosimetric accuracy of treatment delivery [3]. Gel dosimeters offer high resolution 3D information of delivered dose [4, 5]. However the requirement of extensive time for the preparation and readout of gel dosimeters limit their use for routine clinical use [6]. Recently electronic dosimeters have been introduced by many vendors that are able to provide 3D or quasi 3D dose information [7]. Octavius 4D (PTW, Freiburg, Germany), is one such system that provides measured 3D dose matrices of the VMAT plans. McGarry *et al* [8] studied the performance of the Octavius 4D system in the verification of rotational delivery using a Truebeam (Varian Medical Systems, Palo Alto, CA, USA) linear accelerator (linac). In their work the synchrony of the Octavius 4D rotational unit with Linac gantry was tested for discrete gantry angles. In this work we present the validation of the Octavius 4D system for the dosimetric validation of VMAT plans with an Elekta-Synergy linac. We also tested the synchrony of the Octavius 4D rotational unit with linac gantry throughout arc delivery at six different gantry speeds including minimum and maximum speed of the gantry.

2. Materials and Methods

2.1. Octavius 4D dosimetric system

The Octavius 4D dosimeter consists of a cylindrical unit of 32cm diameter and 34cm length that houses a 2D array detector. The measurement plane of the detector array aligns with the centre plane of the cylinder. The cylinder has the capability to rotate in synchrony with the linac gantry using input from the inclinometer. Two types of detector arrays, Octavius Detector 729 and Octavius Detector 1000SRS can be used for the measurement. All the measurements in this study were performed using the Octavius Detector 729 array that has 729 cubic ion chambers uniformly arranged in a 27 x 27 cm^2 area. Each ion chamber has dimensions 0.5cm x 0.5cm x 0.5cm. The Verisoft, v5.1, software was used for the measurement and dose analysis. During measurement the software integrates the frames for every 200ms and these dose planes in conjunction with gantry angle information from the inclinometer and user provided Percentage Depth Dose (PDD) measurements for field sizes ranging from $4x4cm^2$ to $26x26cm^2$ measured at 85cm Source to Surface Distance (SSD) are used for the reconstruction of a 3D dose matrix. The Octavius system was calibrated to measure the absolute dose as per the manufacturer recommended calibration procedure.

2.2. Planning and delivery system

A 6MV photon beam model for an Elekta –Synergy linac in the Pinnacle (Philips Ltd, USA) treatment planning system (TPS), v9.6, was used to generate all the treatment plans in this study. The Elekta – Synergy linac used in this study has the MLCi head and the VMAT plans were delivered with a continuously variable dose rate (CVDR) using Integrity, v1.1, console software.

2.3. Validation of synchronisation of cylinder and linac gantry rotation

The accuracy of the 3D dose matrix calculated by the Octavius 4D depends on the accurate synchronisation of the rotation of the cylindrical unit with the linac gantry. In order to test the synchronisation between the cylindrical unit and linac gantry, dose resulting from treatment arcs with an open field of 10x10 cm^2 and different gantry speeds ranging from 1˚/min to 6˚/min was measured. The gantry position for these arcs as a function of time was plotted using the service plot function in the Elekta_Synergy linac. Similar data was generated from the Octavius measured raw data using the sampling time interval and registered gantry angle. The synchronisation of the Octavius and linac gantry was assessed by comparing the angular position of the cylindrical unit and the linac gantry by comparing these data with respect to the radiation delivery start and detection time.

2.4. Validation of standard and clinical plans

The Octavius system reconstructs the 3D dose matrix based on measured planar dose and user supplied PDD information. The accuracy of the 3D dose matrix reconstructed by the Octavius system for open static and arc fields was compared with the Pinnacle calculated dose matrix. Thirteen clinical VMAT plans, consisting of prostate, prostate bed and head & neck, were also verified using the Octavius system. Some of the key characteristics of static open field, open arc field and clinical VMAT plans are shown in table1. The Octavius reconstructed and Pinnacle calculated dose matrices were compared using 3D gamma (γ) analysis with 2%/2mm and 3%/3mm tolerance criteria and 10% dose threshold [9].

Table 1. Key characteristics of the studied static field, arc and VMAT plans.

Parameter value	Static field	Arc	VMAT plans
Field size	$3x3m^2$ to $25x25cm^2$	$5x5cm^2$ to $25x25cm^2$	
Arc Length		180˚	210˚ to 310˚
Collimator angle	0˚	0˚	10˚
Control-point spacing			2˚ to 4˚

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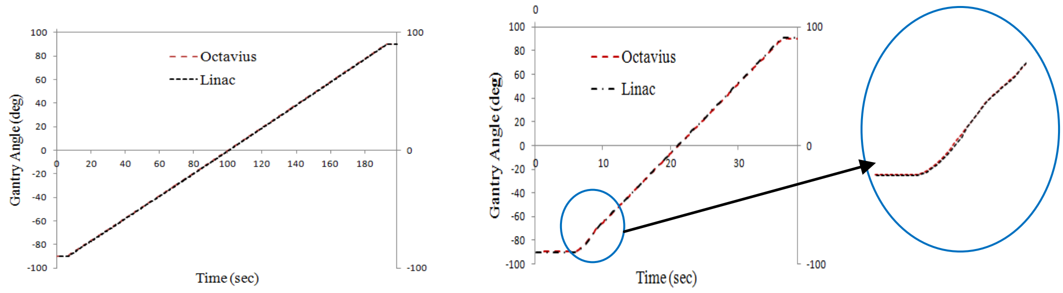
3. Results and Discussion

Figures 1a and 1b show the angular positions of the Synergy linac gantry and Octavius during the slowest and fastest possible arc delivery. The insert of figure 1b shows that linac gantry movement is slightly non linear at the start of the fastest arc. The cylindrical unit of Octavius closely follows the gantry at both fastest and slowest speeds.



a b

Figure1. Synchronisation of the Octavius cylindrical unit with linac gantry for a slowest speed and b.fastest of gantry rotation speeds.

Figure 2 shows the gamma pass rates with 2%/2mm and 3%/3mm tolerance criteria for static open fields, open arc and clinical VMAT plans. In general, the absolute dose agreement between the 3D dose matrix reconstructed by Octavius and Pinnacle agreed very well. This ensures the correct implementation of PDDs used for the reconstruction of 3D dose and accurate field size response of Octavius phantom and detector array. However the Octavius reconstructed dose matrices showed broader shoulders at the field edges due to the relatively larger detector size. This resulted in reduced pass rates for some of the static open fields (figures 2 and 3) when the edge of the field falls on the active volume of the detectors. The dose reconstructed for open arc fields also showed failed gamma voxels at the edges of the field for some of the arcs (figure 2). Mean (1σ) γ pass rates of 84.5(8.9) % and 94.2(4.5) % was observed for 2%/2mm and 3%/3mm tolerance criteria for the studied open arc plans. Figure 4 shows Pinnacle and Octavius calculated dose matrices in axial, sagittal and coronal planes and the γ analysis results in corresponding planes. The clinical VMAT plans showed mean γ pass rates of 86.8(3.5) % and 96.7(1.4) % for 2%/2mm and 3%/3mm tolerance criteria.

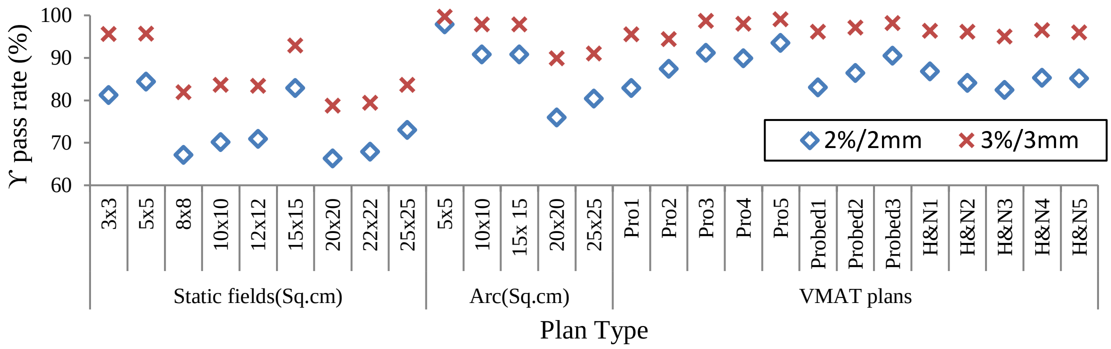


Figure 2. Gamma pass rate of static open fields, open arc and clinical VMAT plans.

The 3D dose information provided by the Octavius system enables the verification of delivered dose in the entire treatment volume (figure 4). The coarse resolution and relatively large active volume of the detectors in the 729 detector array resulted in failed voxels in high dose gradient regions of the measured static open field, arc field and clinical VMAT plans. The observed 3D γ pass rates for the clinical VMAT plans with 3%/3mm and 2%/2mm tolerance criteria are comparable with γ pass rates reported for VMAT plans using other detectors [7, 10, 11].

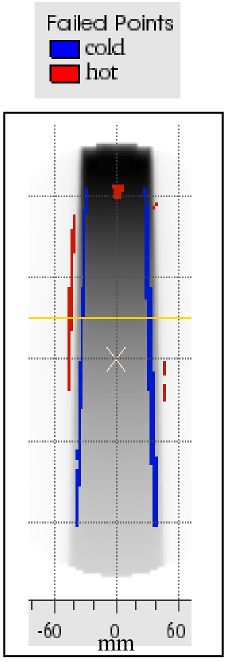


Figure 3. Gamma analysis results for 5x5 cm^2 static field.

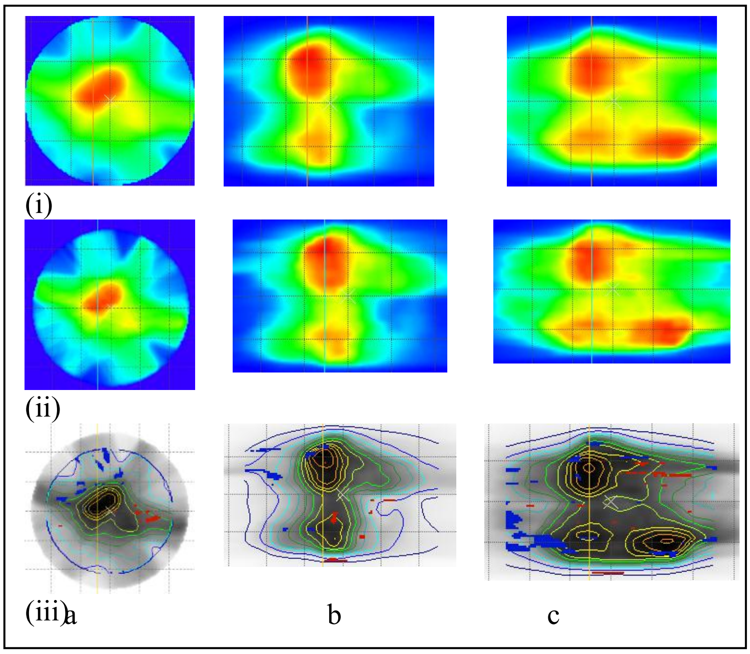


Figure 4. (i) Pinnacle and (ii) Octavius calculated dose matrices in a.axial, b.sagittal and c.coronal planes. (iii) Gamma analysis results with 3%/3mm criteria for a.axial, b.sagittal and c.coronal planes.

4. Conclusion

The Octavius 4D system has been shown to accurately predict 3D dose based on measurement and PDD information. The cylindrical unit of the Octavius 4D system has been shown to rotate in synchrony with the Elekta-Synergy gantry at both slowest and fastest speeds. However, due to the coarse resolution of the detectors and a relatively large detector size failed pixels were observed on the penumbra region of the conventional treatment fields and high dose gradient region of VMAT plans.

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6. References

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