A systematic study on the angular dependence of 2D ion chamber array for accurate IMRT plan quality assurance

J. Xu, J. Liu, I. T. Veltchev, R. A. Price, C. Ma

Fox Chase Cancer Center, Philadelphia, PA, USA,

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INTRODUCTION & AIM

To clinically implement the AAPM Task Group 218 recommendations on measurement-based IMRT plan QA, a systematic study on the angular dependence of IBA MatriXX^{Evolution} 2D ion chamber array was performed and γ dose distribution comparison metrics based on homogeneous vs. heterogeneous geometry was evaluated.

METHOD

The IBA MatriXX^{Evolution} system was set up in the horizontal position, and dose maps were recorded for gantry angles of 0°-180° at different field sizes ranged from 3×3 to 28×28 cm^2. Angular correction factors (CF) were derived as the ratio of the chamber readings to the TPS-calculated doses as a function of gantry angle for both homogeneous "water" (HU = 0) and inhomogeneous MatriXX geometry. Following recommendations of AAPM TG-218, IMRT plan QA measurements were performed using the true composition delivery method and the results were analyzed using a tight γ test criterion of 3%/2mm with a 10% threshold.

RESULTS

The main features of an angle-resolved dose profile are dominated by the phantom attenuation, with a sharp fine structure around 90˚, which is attributed to the attenuation from the internal electronic circuit plate underneath the ion chambers. The angular correction factors showed a strong field size dependence (maximum CF difference ~4% at 6MV and ~2.5% at 10MV), and large chamber-location variation (maximum ~7% from central chambers). In general, there was a smaller variation of CF over field size and a more uniform CF cross the chamber array using homogeneous "water" than inhomogeneous geometry. This is further confirmed by the passing rate improvement in γ tests of real patient IMRT plans using homogeneous vs inhomogeneous phantoms.

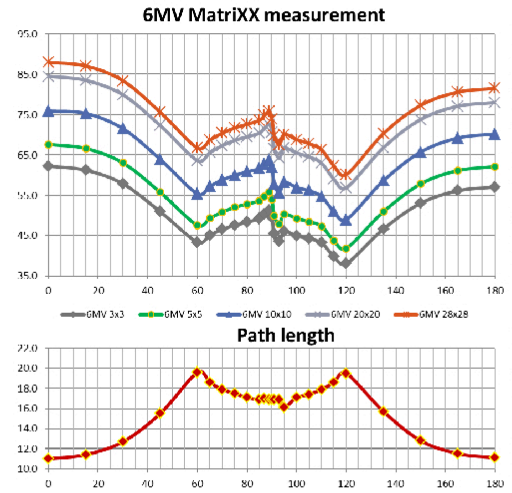


Figure 1 | Angle-resolved absolute dose profile recorded using MatriXX^{Evolution} 2D ion chamber array at 6MV for 5 different field sizes, 3x3 cm^2, 5x5 cm^2, 10x10 cm^2, 20x20 cm^2, and 28x28 cm^2 (Upper Panel).

As expected, the dose drops as field size decreases. The main features of the angle-resolved dose profile, peaked for AP/PA beams and dipped at 60º and 120º, are dominated by the phantom attenuation, as characterized by the beam path length in the phantom (Lower Panel). A sharp fine structure around 90º is caused by the beam attenuation from the internal electronic circuit plate underneath the ion chamber array.

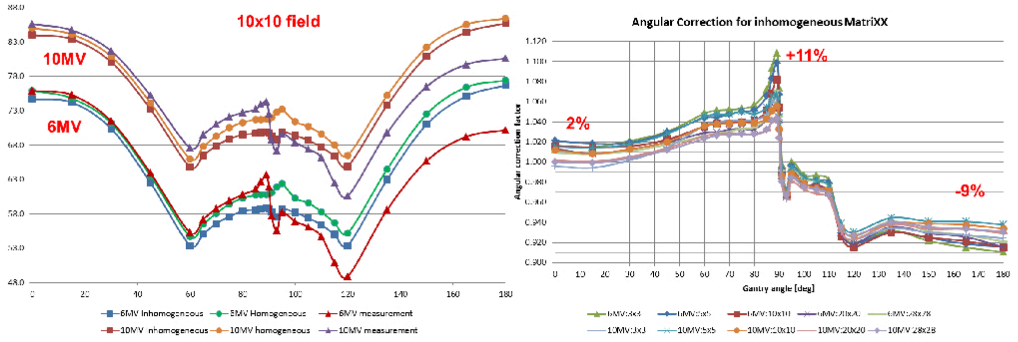


Figure 2 | Left: Measured dose profile vs gantry angle for the central chambers at 6MV and 10MV for a 10x10cm^2 field, in comparison with the TPS-calculated doses with inhomogeneous and homogeneous "water" MatriXX geometry. Right: Angular correction factor (CF) derived for the central chambers.

TPS dose calculations with both phantoms do not fully predict the measurement data, especially at large beam angles. This is the angular dependence of the MatriXX 2D ion chamber array, and therefore angular correction to the recorded doses needs to be performed in order to compare with the TPS calculations for gamma test. Angular correction is small for AP beams (~2%) and large for lateral (~11%) and PA beams (~ -9%). There are by far two main angular correction methods, central correction and entire correction. The former simply applies the derived angular correction factor for the central chambers to the whole array, while the latter basically uses chamber-specific CFs, which has to be determined with large fields (>28x28 cm^2) for all ion chambers.

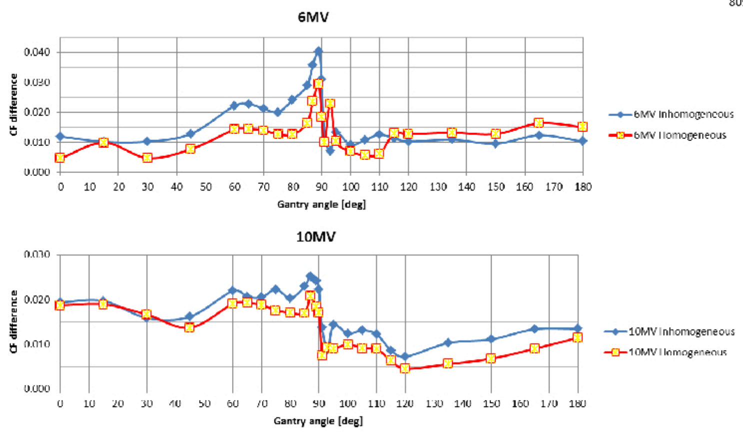
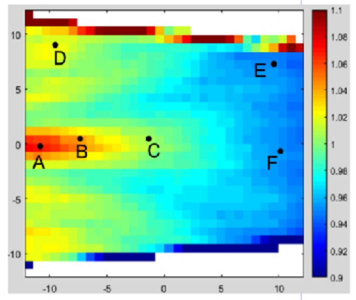


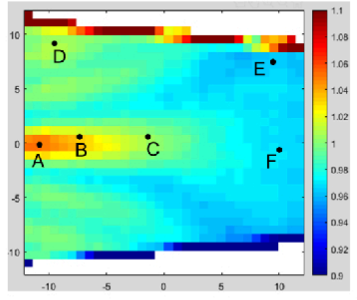
Figure 3 | Maximum variation of angular correction factors over field size as a function of gantry angle for inhomogeneous & homogeneous Matrixx geometry at 6MV (Upper Panel) and 10MV (Lower Panel).

Angular correction factors showed a strong field size dependence for inhomogeneous phantom with maximum CF variation ~4% at 6MV and ~2.5% at 10MV around gantry angle 89º. In general, a smaller variation of CF over field size was shown using homogeneous than inhomogeneous phantoms. The field size effect may cause inaccuracy in gamma test with the entire correction method as small segments are largely used in patient IMRT plans.



Inhomogeneous

A	B	C
1.070	1.041	1.007
D	**E**	**F**
1.021	0.950	0.952



Homogeneous (HU=0)

A	B	C
1.051	1.033	1.006
D	**E**	**F**
1.008	0.964	0.968

Figure 4 | Variation of 2D angular correction factors cross the ionization chamber array at 90º for a 20x20 cm^2 field for inhomogeneous (Left) and homogeneous "water" (Right) MatriXX geometry.

The variation is quantified as the ratio of the CF of a specific ion chamber to the averaged CF of the 4 central chambers, and the variations for 6 representative chambers are tabulated below each subfigure. The 2D angular CF with the inhomogeneous phantom shows a large chamber-location variations, ranged from ~-5.0% to ~7.0%, while 2D variation is reduced when homogeneous "water" phantom is used, ranged from ~-3.8% to ~5.1%. The 2D CF variation may cause inaccuracy in gamma test with the central correction method. There is no perfect solution for the angular correction in 2D array dosimeter, however, with the homogeneous "water" phantom, one can reduce the field size effect and 2D CF variation.

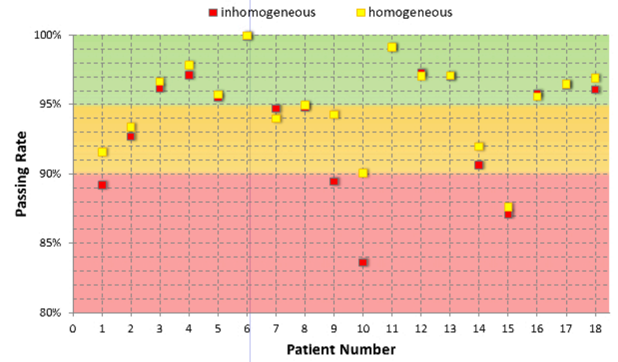


Figure 5 | Statistical study on gamma test passing rates of real patient IMRT plans using homogeneous vs heterogeneous (yellow vs red squares) MatriXX geometry.

Following AAPM TG-218, IMRT plan QA measurements were performed using the true composition delivery with angular corrections and a tight γ test criterion of 3%/2mm with a 10% threshold were used. A total of 18 cases were studied, covering different beam energies, treatment machines, & tumor sites. Passing rate improvement was observed in 15 cases with homogeneous "water" vs inhomogeneous phantom, with significant improvement in 3 cases (increased by 2.4-6.5%). Passing rates were slightly higher (0.1-0.7%) in 3 cases for inhomogeneous than homogeneous phantom, which is, however, clinically insignificant.

CONCLUSIONS

A systematic study was conducted on the angular dependence of IBA MatriXX^{Evolution} 2D ion chamber array system. IMRT plan verification with homogeneous "water" MatriXX geometry has been developed for the clinical implementation of AAPM TG-218.

REFERNCES

M. Miften et al. "Tolerance limits and methodologies for IMRT measurement-based verification QA : Recommendations of AAPM Task Group No. 218" , *Med. Phys.* ***45***, e53-83 (2018)