Gamma Criteria Use in Monthly Profile QA

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Purpose

To determine if using a gamma analysis is a reasonable alternative to traditional TG-40 tests for monthly QA by comparing passing rates for inline and crossline profiles with manufactured errors in flatness, symmetry, and energy.

If gamma proves a possible alternative to traditional monthly profile QA methods, then an acceptable gamma criteria and passing threshold should be selected that most closely matches that of traditional methods.

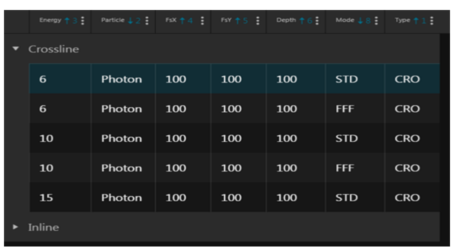
Objectives & Tools

Objectives:

- Determine whether gamma criteria can be used as a an effective replacement for existing monthly profile QA criteria
- Develop a method to manufacture errors in flatness, symmetry, and energy so that some variations will be in and some out of tolerance
- Test the scans to determine whether the manufactured errors are caught by traditional methods
- Compare scans with new gamma criteria method using multiple criteria to determine which most closely matches traditional methods
- For energy constancy, Dmax must be found for each default energy and with the beam hardened using the copper plate

Tools:

- Profiles were all collected on a MatriXX ion chamber array with OmniPro ImRT software. Distance between chambers is 7.62 mm center-to-center, and the maximum active measurement area is 24.4 cm by 24.4 cm limiting the possible field sizes for the experiments
- OmniPro software was only used to scale the data show the maximum point as 100%. No changes were made to the resolution
- Profiles were exported to Quadrant for comparison. Gamma pass rates as well as flatness and symmetry were calculated in Quadrant



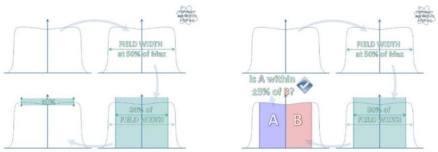
	Energy	Particle	FsX	FsY	Depth	Mode	Type
Crossline							
	6	Photon	100	100	100	STD	CRO
	6	Photon	100	100	100	FFF	CRO
	10	Photon	100	100	100	STD	CRO
	10	Photon	100	100	100	FFF	CRO
	15	Photon	100	100	100	STD	CRO
Inline							

Materials & Methods

Traditional Criteria: TG-40 monthly requirements for photon flatness, symmetry, and energy (central axis constancy) are 2%, 3%, and 2% respectively.

Flatness was calculated as $(Dmax-Dmin)/(Dmax+Dmin)*100\%$ from the middle 80% of the field width. Field width was determined by the FWHM.

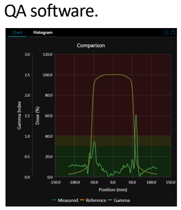
Symmetry was determined by comparing the area under the profile across the central axis within the middle 80% of the field. The field width was defined by the FWHM.



The method to determine whether energy fell within tolerance was to measure each energy at Dmax and 5 cm depth. The energy was determined by the ratio of Dmax and 5 cm values. Initial measurements were taken with a block tray. A copper plate was added to the tray to cause energy deviation. A shift in the ratio of 2% or more would represent that the energy was out of tolerance. Profiles were then collected and compared between the Copper plate and empty tray fields.

Profiles for flatness, symmetry, and energy were taken at 5 cm and 10 cm depth with 10x10 cm and 20x20 cm fields at 100 SSD on a MatriXX array. Solid water was used to simulate the depth.

Beam profiles with altered flatness were obtained by rotating the gantry angle from 0 to 5 degrees in 1-degree increments. Symmetry was altered by placing additional layers (2 mm to 15 mm) of solid water on half of the scan. Energy was altered by placing a copper plate in the beam over the entire field. The experiment was performed with the following energies; 6x, 6FFF, 10x, 10FFF, and 15x. Data was analyzed using Quadrant, an in-house profile QA software.



All gamma criteria and flatness/symmetry measurements used to compare profiles were calculated in Quadrant. Flatness and symmetry profiles were compared using 1%/1mm, 2%/2mm, and 3%/3mm against the commissioned data scans for the machine. Energy was compared between the block tray and copper plate data.

Results

The flatness, symmetry, and energy results were evaluated using three different sets of gamma criteria (1%/1 mm, 2%/2 mm, 3%/3mm), and using traditional methods. The passing rates for gamma analysis are 88-93%, 95-98%, and 98-100% respectively for profiles with traditional flatness of 2% or less. Symmetry results are 24-79%, 94-98%, and 100% respectively for profiles with traditional symmetry of 3% or less. The results are 62-100%, 100%, and 100% respectively for energy profiles with central axis constancy of 2% or less

Flatness:

Flatness 10 cm depths 10x10						
Energy	Flatness	Crossline				
		Gamma			TG 40	
		1%/1mm	2%/2mm	3%/3mm	Flatness	Symmetry
10x	0	91.4%	97.8%	100.0%	1.9%	1.2%
	1	89.2%	95.7%	98.9%	1.6%	0.7%
	2	77.4%	87.1%	92.5%	2.2%	1.6%
	3	67.7%	78.5%	86.0%	3.1%	3.5%
	4	59.1%	73.1%	78.5%	4.5%	6.3%
	5	53.8%	68.8%	74.2%	7.4%	11.4%

Symmetry:

Symmetry 10 cm depth 20x20						
Energy	Symmetry	Inline				
		Gamma			TG 40	
		1%/1mm	2%/2mm	3%/3mm	Flatness	Symmetry
15x	2mm	86.0%	96.8%	100.0%	2.0%	1.6%
	5mm	53.8%	96.8%	100.0%	2.4%	2.4%
	1cm	25.8%	59.1%	98.9%	3.3%	4.2%
	1.5cm	7.5%	16.1%	95.7%	4.1%	6.0%

Energy:

Energy 10 cm depth 20x20							
Energy	Plate	PDD Shift	Crossline				
			Gamma			TG 40	
			1%/1mm	2%/2mm	3%/3mm	Flatness	Symmetry
6x	Tray	-1.5%	62.4%	100.0%	100.0%	3.1%	1.8%
	Cu					3.3%	1.8%
6FFF	Tray	-1.4%	100.0%	100.0%	100.0%	NA	1.8%
	Cu						1.6%
10x	Tray	-2.1%	55.9%	93.5%	100.0%	2.4%	1.5%
	Cu					2.9%	1.4%
10FFF	Tray	-0.9%	100.0%	100.0%	100.0%	NA	1.7%
	Cu						1.6%
15x	Tray	-0.3%	68.8%	100.0%	100.0%	2.4%	1.4%
	Cu					2.4%	1.4%

The tables above are samples from the total collected data. The header shows the test being performed. The left columns show beam energy and degree of error introduced into the field. The middle section gives pass rates for the different gamma criteria. The right columns give the calculated flatness and symmetry.

Discussion

Traditional TG-40 criteria of 2% flatness and 3% symmetry requirements have transitioned to 1% constancy in TG-142. This leads to a great deal of variation in determining whether a field has passed or failed. Taking a different set of points could offer different results for the same scan. Despite this, the inclusion of constancy instead of a static value like flatness or symmetry has the advantage of checking what is truly important, that the data used in the calculation model is comparable to what the machine is delivering.

While advantages exist with both of these methods, so too do disadvantages. In this project, gamma analysis was put forward as a possible bridge between the two methods. It serves to give a more definitive result on whether a field is passing or failing, while giving flexibility to accept slight variations between linear accelerators.

Through comparisons between multiple energies and with the introduction of manufactured errors, this experiment showed 2%2mm with a 95% threshold to most closely matches pass rates with older standards of flatness and symmetry while having the benefit of being usable with flattening filter free beams.

3%/3mm proved too loose in several instances, offering high gamma pass rates in fields that fail flatness and symmetry checks. This is most clearly seen in the symmetry test for the 15x beam. Symmetry is calculated as 6%, well outside the 3% tolerance, yet the gamma criteria shows a near 96% pass rate.

1%/1mm was noticeably too tight a criteria. Even the slightest alterations that should still fall within tolerance cause a sharp fall in pass rates. The test for flatness with 10x shows even with no change in the field, the pass rate was still only 91.4% when compared to the commissioned data.

One area the defied this trend is when testing energy change. Gamma criteria proved not very effective as a tool for discerning energy change outside of tolerance. In most cases, the pass rate was 100% even with some 1%/1mm criteria. In addition, despite nearly the same change in central axis (CAX) constancy between 6x and 6FFF, the results for 1%/1mm were nearly 40% different.

Conclusion

The data from this study indicates using a 2%/2mm gamma criteria with a 5% failure threshold could serve as an effective replacement for traditional profile QA tests for determining whether flatness and symmetry or profile constancy during monthly tests is within tolerance. CAX constancy or energy, however, should not be evaluated using gamma criteria.

Contact & Acknowledgements

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