Delta4 – A New IMRT QA Device

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Purpose

The basic capabilities of a 4D dosimetry and quality control device were evaluated in a clinical setting. QA measurements of dynamic treatment modalities such as IMRT, 4DRT, ARC, IMAT, gating and TomoTherapy were perform. Dose delivered was measured in short time intervals allowing for a comparison of the total dose delivered with the treatment plan.

Method and Materials

Simultaneous measurements were performed with a Delta^4 QA-device of absolute dose and dose distribution in 4-dimensions including time. Comparison was done to a Farmer type NE 2571 chamber.
Some of the basic characteristics was done in flat phantom.
Monitoring units and segment weighting in IMRT, fields, beams and composite plan were verified. Errors were quantized and analyzed; leaf sequence files were also verified.

Measurement accuracy using Delta^4

Delta^4 uses a new p-Si diodes. Previous Si-diodes on the market are known to have very good spatial resolution and simple to use but the drawback of over response to low energy photons. The clinical relevance is possible discrepancy in the response at various depths, field sizes and outside the primary field. The new p-Si diode was compared to a Farmer type chamber e.g. NE 2571 at clinical relevant conditions.

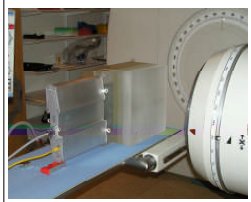
All test where done with IC and diode in the same position; standard deviation typically in the range 0.2 - 0.5 %.

Dose linearity test: Simply a change in MU

DPPD test: Constant build-up, back scatter and field size at detector; IC corrected for recombination, various SDD was used to change dose per pulse without changing energy spectrum.

Field dependency test: Constant SDD; changing field size at various depths; normalization at 10x10 cm2

Depth dependency test: Constant SDD and field size 10x10 cm2; various depths and back scatter total thickness 22cm (same as Delta^4), normalization at reference depth



Dose linearity Delta^4

	Ratio Delta^4 / IC chamber (%)				
	10 MU	20 MU	50 MU	100 MU	200 MU
Average (100detectors)	100.0	100.0	100.0	100.1	100.1

DPPD (Dose Per Pulse Dependency)

SDD (cm)	Dose/pulse (mGy)	Ratio Delta^4 / IC chamber (%)
86,5	0,18	100.0
104,5	0,12	100.5
130,5	0,07	100.5
260,5	0,02	100.2

Field size dependency Delta^4

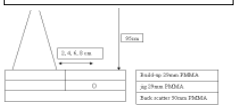
		Ratio Delta^4 / IC chamber (%)			
Energy	Depth (mm)	50x50 mm^2	100x100 mm^2	150x150 mm^2	200x200 mm^2
6MV	15	99.7	100.0	100.7	101.2
	45	99.7	100.0	101.2	102.2
	105	99.1	100.0	101.7	102.8
	205	99.1	100.0	101.4	102.5
15MV	15	99.8	100.0	99.7	99.9
	45	99.7	100.0	100.4	101.1
	105	99.7	100.0	100.6	101.7
	205	99.7	100.0	100.7	101.3

Depth dependency Delta^4

10x10 cm^2	Ratio Delta^4 / IC chamber (%)			
Energy	15 mm	45 mm	105 mm	205 mm
6MV	99.8	100.0	100.9	100.4
15MV	101.4	100.0	100.5	100.1

Out of filed dependency

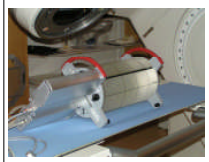
Deviations between Delta^4 and IC measurement outside the field as percentage of dose in the reference point for various field sizes and distances to the field edge.

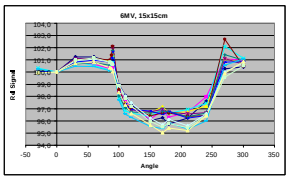


Out of field dependency Delta^4

		Ratio Delta^4 / IC chamber (%)		
Energy	Distance to field edge (mm)	50x50 mm^2	100x100 mm^2	150x150 mm^2
6MV	20	0.5	0.9	1.3
	40	0.3	0.8	1.0
	60	-----	0.6	0.8
	80	-----	-----	0.7
15MV	20	0.3	0.2	1.1
	40	0.2	0.3	0.8
	60	-----	0.2	0.7
	80	-----	-----	0.8

Test of the Delta^4 **directional dependency**, no measurement true patient table top.



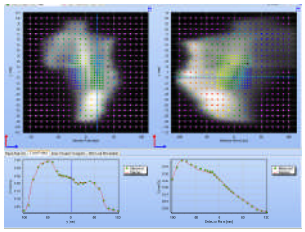


QA in various applications using Delta^4

Delta^4 measures the dose distribution in a modern way, synchronized with the accelerator trig pulses, all detectors parallel. Data is stored individually for each dose pulse together with instant information on external systems e.g. MLC settings, gantry angle, gating, 4DRT etc. making the system extremely flexible to various treatment techniques. Data from the same measurement was compared to plan data both per fraction, beam and segment (MLC comparison due to non available data from TPS) in the two measuring planes.
Similarly data was calculated from the measuring planes to be shown for the complete volume per fraction and per beam and compared with TPS data. DVH where compared for the semi-measured data with the TPS data for the patient structures applied to the phantom to evaluate the significance of any deviation.

Measurement result from two crossing 2D arrays from head and neck case. Measurement accuracy typically better than 2%

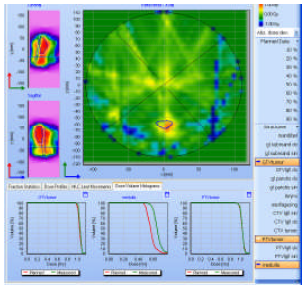
Measurement and TPS data in the two detector planes displayed as dose deviation (could be DTA, gamma index etc as well). A profile true the 2D array displays 1D data comparing measured data and TPS data.



Fraction data from Delta^4 dispalyed as dose deviation in a color washed axial view and DVH to focus on deviations in the important structures.

Each beam-ray intersecting with the measurement planes and the dose along the rays is calculated utilizing the relation from the TPS dose data per beam.

Patient structures are introduced in its relative position to isocenter. The dose in each structure is the phantom dose calculated from TPS data and for the measured data.



Results

The p-Si diodes in the Delta^4 QA-device showed a very small field and depth dependency of less than 1.5%, a decrease in sensitivity of less than 1% per kGy, and a temperature dependency of less than 0.4% per degree C°. Due to the high accuracy of the measurement small correction factors could be applied for field size, depth, directional and temperature dependency. The overall accuracy of measurement in the primary field was better than 2%. Its application software allowed to displayed semi-measured data in the transversal planes and in DVH to distinguish deviations in critical organs and tumor from other less sensitive tissue.

Conclusion

The Delta^4 measures each dose pulse individually making it possible to view data in any time-increment as: plan, beam, segment, control point, respiratory phase, and angle increment. Measurements were directly compared with the dose distribution for a composite treatment, saving extensive time in evaluation of good plans. Data analysis can be refined to beam and sub beam level using the data acquired during one single delivery and thereby significant time is saved. No restrictions or changes has to be introduced to the patient treatment plan because the QA-device is placed on the couch and irradiated with the same plan. Also effects like couch attenuation can be re-viewed.