Patient plan verification with diode arrays

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Purpose: To establish effective methods for patient IMRT plan verification using the Delta4 (ScandiDos, Uppsala, Sweden) and MapCheck (Sun Nuclear, Melbourne, Florida) diode arrays. And to show how the ability of the Delta4 to measure the dose from individual IMRT beamlets can be used to investigate IMRT delivery.

Method - Patient Plan Verification: The MapCheck is a single 22cm by 22cm array of 445 diodes with build-up equivalent to 2cm of water. We use it with an in-house rotating mounting so as to measure at different gantry angles with the beam perpendicular to the array. The Delta4 contains three arrays with a total of 1069 diodes that are arranged to form two orthogonal planes within a 22cm diameter PMMA cylinder. Patient step and shoot IMRT plans for the treatment of prostate, head and neck and mesothelioma tumours were verified. The plans were created on the Philips Pinnacle treatment planning system and delivered using Varian linacs.

Method – Investigation of Variation in Beamlet Dose: The ability of the Delta4 to easily record the dose for individual IMRT beamlets allows further investigation of IMRT delivery. For example, most treatment planning systems would calculate the same planned dose for an IMRT beamlet regardless of whether the beamlet is the first, middle or last beamlet within an IMRT beam. Measurements were made with the Delta4 to test whether is assumption is correct. In the sequence of beamlets illustrated in fig.3, the 1st, 3rd and 5th beamlet are identical, as are the 2nd and 4th. An IMRT beam with these beamlets was delivered with 2MU for each beamlet and with 10MU for each beamlet, on three different Varian linacs at 6MV.

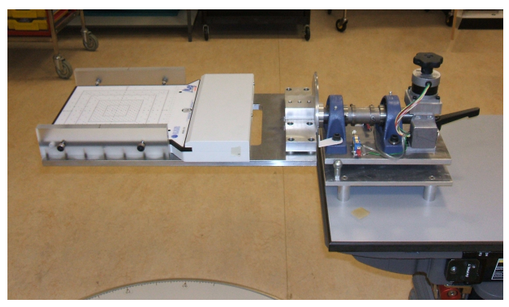

Fig.1 Mapcheck Diode Array on In-house Rotating Platform

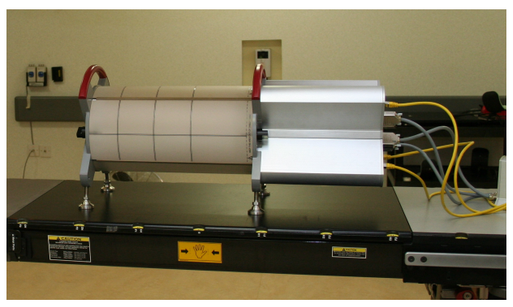

Fig.2 Delta4

	Mapcheck	Delta4
Number of diodes	445	1069
Geometry	1 plane	2 perpendicular planes
Array size	22cm by 22cm	22cm by 22cm
Diode spacing in inner region	7mm	5mm
Diode spacing in outer region	14mm	10mm
Build Up (water equivalent)	2cm	1.2 cm to 13.2cm for nearest detector board

Table.1 Comparison of Mapcheck and Delta4

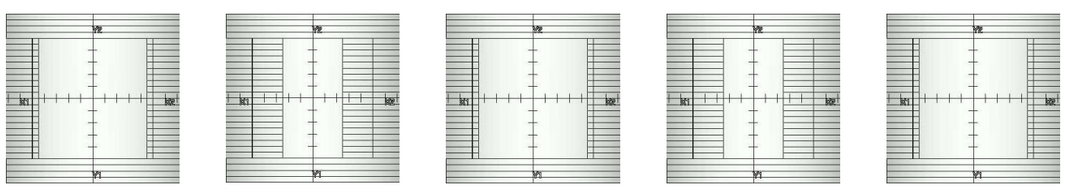

Fig.3 Beamlets for Investigation of Output per Beamlet Variation (Jaws 10cm by 10cm and MLC shaped field 9cm by 10cm or 5cm by 10cm)

Results –Patient Plan Verification : The gamma index, (Low et al 2003), was used to compare measured and planned dose distributions. Only diodes at positions with greater than 20% planned dose were tested. A beam was considered to have passed when more than 95% of the tested diodes passed the gamma test. Beams which failed the test were investigated further.

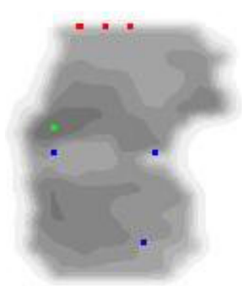

Fig.4 Example Analysis of Beam Results with Mapcheck

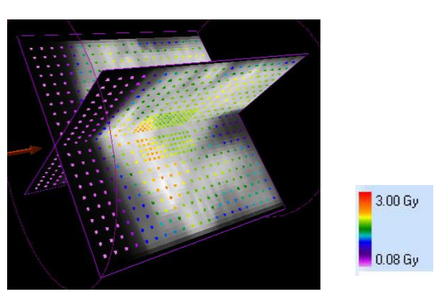

Fig.5 Example Analysis of Beam Results with Delta4

The results of patient plan verifications with the Mapcheck diode array are shown in table 2. These results exclude 3 patients, where a record and verify system fault caused the closed MLC pair junctions to be placed within the field rather than outside of it. The Mapcheck results for these excluded patients were noticeably poor. Fig.6 shows an example analysis of a IMRT beam in Mapcheck. The grey scale indicates the planned dose, the red and blue dots indicate diodes which failed a 4%/3mm relative gamma test and the green dot indicates a common point of normalisation.

Tumour Category	Energy	Number of Patients	Number of Beams PASS	FAIL
Mesothelioma	6MV	4	60	1
Head and Neck	6MV	14	107	6

Table.2 Mapcheck Results with 4%/4mm Relative Gamma Test

The results of patient plan verifications with the Delta4 diode array are shown in table 3. The Delta4 allows a meaningful gamma test to be performed for the whole fraction dose as well as for individual beams. All the measured beams passed a 4%/3mm gamma test for the fraction dose. The results quoted below are for the tighter 3%/3mm tolerance. Individual beams at gantry angles within 3° of a detector plane angle sometimes produced poorer results on the detector plane which the beam is passing along. The Delta4 software now includes the option to compensate the readings for a known linac daily output. This feature was not used in the results shown below, except for one of the prostate patients with non-standard angles.

Tumour Category	Energy	Number of Patients	LOWEST Total Fraction Diode Pass %
Prostate standard angles	10MV	13	99.5%
Prostate non-standard angles	10MV	3	98.6%
Prostate + pelvic nodes	10MV	3	91.7%
Oesophagus	6MV	4	95.2%
Nasopharynx	6MV	3	98.7%
Other Head and Neck	6MV	3	89.1%

Table.3 Delta4 Results with 3%/3mm Gamma Test

Results – Investigation of Variation in Beamlet Dose: For one of the 3 linacs tested, fig.6 shows the readings on the central diode of the Delta4 for the beamlet sequence shown in fig.3. The results on the other two linacs were similar. At 2MU per beamlet, there are significant differences in the Delta4 measured doses from the identical 1st, 3rd and 5th beamlets. These results are in agreement with those reported by Ezzell and Chungbin (2001). For Varian linac IMRT, they investigated variations in the fractional beamlet MU as measured by the linac ionisation chamber. They found that a delay in the beamlet MU control system caused the MU of the first beamlet to be increased and the MU of the last beamlet to be decreased. At dose rates of 600MU/min, the increase and decrease is approximately 0.6MU and this in independent of the planned beamlet MU. There are also additional smaller variations in delivered beamlet MU. For the beamlet sequence from fig.3, a 0.6MU increase in the first beamlet will cause it to deliver 30% more dose than the 3rd beamlet, when each beamlet is planned to have 2MU, but only 6% more dose, when each beamlet is planned to have 10MU. The measured percentage differences for the beam shown fig.6 were actually 46% and 4%. The Delta4 measurements were verified by videoing ion chamber electrometer readings and playing back the digital video files at one quarter speed.

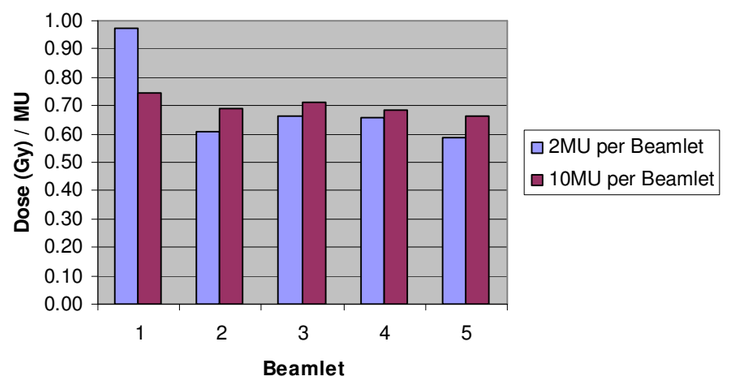

Fig.6 Variation in Output per Beamlet

Conclusion: Diodes arrays are shown to be an effective tool for patient plan verification and a useful addition to the methods for investigating beam delivery.

References:

Ezzell GA, Chungbin S (2001) *J App Clin Med Phys* 2(3) 138-148
Low et al (2003) *Med Phys* 30(9) 2455-64