# Dosimetric verification of vmat dose distribution with DELTA4® Phantom

M. Natali[1], C. Capomolla[1], D. Russo[2], G. Pastore[1], E. Cavalera[2], A. Leone[2], A. Zagari[1], M. Santantonio[2]

[1]*U.O.C. Fisica Sanitaria P.O. "Vito Fazzi", Lecce (Italy)*
[2]*U.O.C. Radioterapia - P.O. "Vito Fazzi", Lecce (Italy)*

## Abstract

Radiation Oncology, has changed a great deal, undergoing an innovation and technical development; there has been an evolution from conformal radiotherapy techniques (3D-CRT), through advanced modalities like intensity-modulated radiation therapy (IMRT) and next volumetric modulated arc therapy (VMAT). VMAT technique requires a dedicated QA (Quality Assurance) procedure for dosimetric verification of a planned dose distribution to check for the agreement between a dose distribution calculated by the Treatment Planning System (TPS) and the corresponding measured dose distribution. Since November 2010, in Radiation Therapy Department of "V. Fazzi" hospital in Lecce (Italy), 257 patients were treated with VMAT and the corresponding dose distribution were verified with the Delta4® diode array phantom. Parameters used in the comparison between calculated e measured dose are the dose agreement (DA), the distance to agreement (DTA) and the $\gamma$-index. The phantom measurements closely match the planned dose distributions in high and low dose-gradient region.

## *Introduction*

Volumetric Modulated Arc Therapy (VMAT) is a new intensity-modulated radiation therapy (IMRT) technique that improves critical structures and healthy tissue sparing, in dramatically shorter treatment times all without comprising target coverage and patient safety.

The sharp dose gradients found in VMAT, make critical the deviations between calculated and real dose distribution even if they are very small, especially in regions close to organs at risk; in addition, each VMAT plan is strictly tailored on the patient because the various leaf position and leaf speed may be quite different, even case of target and organs at risk very similar, because it is dependent on multiple factors, each of them influencing dose effectively delivered to the patient.

Complex radiotherapic treatment plans such as those obtained with VMAT require dosimetric verification before clinical delivery.

## *Materials and methods*

In Radiation Therapy Department of "V. Fazzi" hospital in Lecce (Italy), 257 patients were treated with VMAT.

In our institution, planned dose distribution is checked using the Delta4® diode array phantom.

During verification process the planned treatment is transferred from the patient (Fig 1a) to the phantom (Fig 1b), the treatment plan is recalculated on a CT scan of the phantom and then the dose

distribution is measured using Delta4® device.

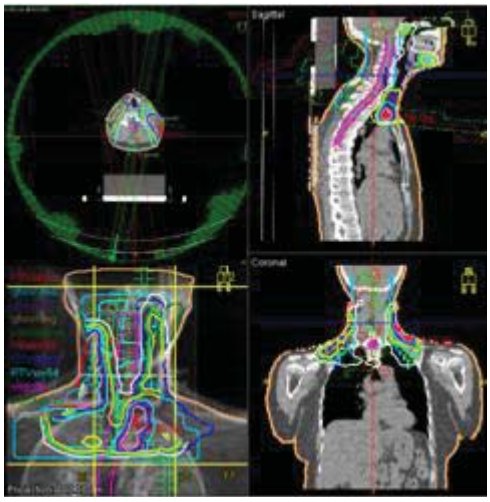


*Fig. 1a VMAT planned dose*

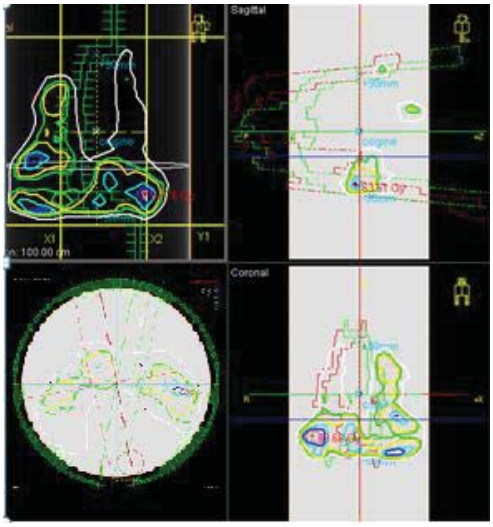


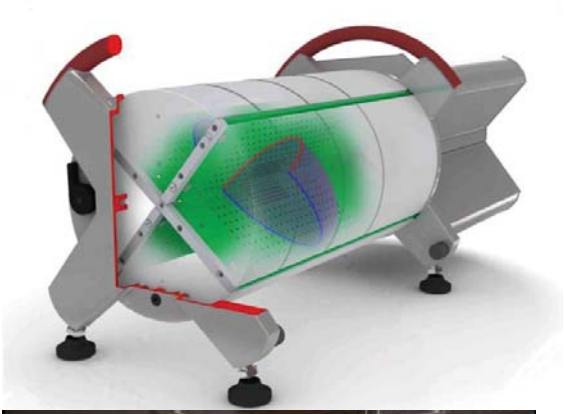
*Fig. 1b recalculated VMAT dose on the Delta4®*

The Delta4® diode array phantom (Scandidos, Uppsala, Sweden) consists of 1069 p-type Silicon diodes in a crossed array inside a cylindrical polymethylmethacrylate (PMMA) phantom with associated a computer software that allows the user to compare the measured dose distribution for a complete treatment plan with the dose distribution predicted by the treatment planning system (Oncentra Masterplan®). The diodes are cylindrical, have an area of 0.0078 $cm^2$ and are spaced at 0.5 cm intervals over the central 6 x 6 cm of the planes and at 1 cm intervals over the remainder of the central 20 x 20 cm of the planes. The crossed planes are achieved by means of a main detector board which passes through the entire diameter of the phantom and two wing detector boards which are separated to allow the main detector board to pass between them. The phantom itself has a diameter of 22 cm and length of 40 cm (Figure 2).

The device records measured dose in relation to the individual accelerator pulses by using a trigger signal from the accelerator, facilitating time-dependent four-dimensional applications. Gantry angle is independently sensed by means of an inclinometer attached to the gantry or accelerator head. This allows the device to identify which control point of a dynamic arc delivery is being delivered, so that the measured dose can be associated with this control point, and the appropriate correction for gantry angle applied.

When the measure with the Delta4® has been performed, the agreement between calculated and measured dose distributions must be analyzed.

A qualitative check of the agreement is usually performed by dose profiles along selected lines or isodose comparisons.



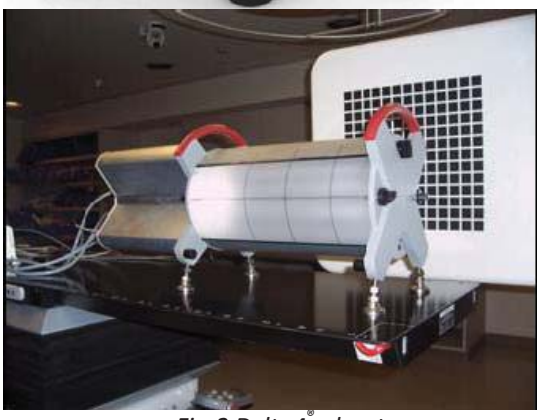


*Fig.2 Delta4® phantom*

If quantitative comparisons are required, the choice of the correct parameters to be employed is critical.
In standard techniques, the most important parameters are: “dose agreement” or DA and “distance to agreement” or DTA.
DA is the percentage or absolute difference between measured and calculated dose, unfortunately it is not suitable for high dose gradient region, where even small spatial errors may lead to large but not significant errors. So in high dose gradient regions it is used the DTA, defined as the minimum distance, in the plane, between a measured point and the nearest point in the calculated dose distribution that has the same dose. It is defined 3mm as distance limit.
It is important to underline that DTA depend on the choice of the correct common coordinate system between measured and calculated dose, otherwise results are not significant.
The DTA and the DA% are quantitative tools but they still have important limitations when applied to IMRT dose distributions.
To overcome all these problems, a new parameter ($\gamma$-index) that it includes in a single data set DA% and DTA has been introduced.
The $\gamma$–index is defined as follows: given a point in the reference distribution, $r_r$ , and the relative dose $D_r$, an “acceptance ellipsoid” for point $r_r$ is defined by :

$$\gamma(\vec{r}_m) = min\left[\sqrt{\left(\left(\frac{\delta d(\vec{r}_m,\vec{r}_c)}{\Delta d_M}\right)^2 + \left(\frac{\delta r(\vec{r}_m,\vec{r}_c)}{\Delta r_M}\right)^2\right)}\right]_{\forall \vec{r}_c}$$

$\Delta d_M$ e $\Delta r_M$ the acceptance criteria for distance e dose
$\delta r$ is the distance between the measured point $r_m$ and a point $r_c$ chosen in calculated dose distribution
$\delta d$ is the corresponding dose difference.
As a general rule, acceptance criteria of 3 % dose difference and 3 mm distance to agreement are adopted and more than 90%-÷95% of points passing the chose criterion.

## *Results*

All 257 VMAT treatment plans were recalculated on a CT scan of Delta4® phantom and the corresponding dose distributions were verified with the Delta4® diode array phantom.
All plans were analyzed using the three parameter %DA (limit 3%), DTA (limit 3%), (limit 3 mm), and $\gamma$-index with the 3% dose tolerance and 3 mm distance to agreement in relation to the treatment planning system.
The gamma criterion was considered fulfilled if $\gamma < 1$ in at least 90÷95% of the points.
Results confirmed a good agreement between the two distribution with high and conformed dose to the target and low dose to the organ at risk.
Fig.3 shows Delta4 output for head and neck cases, the planned dose distribution in grayscale and the measured dose in color over the wing detector boards (at left) and the main detector board (at right) and the histograms of %DA, DTA, and $\gamma$-index are in reported.

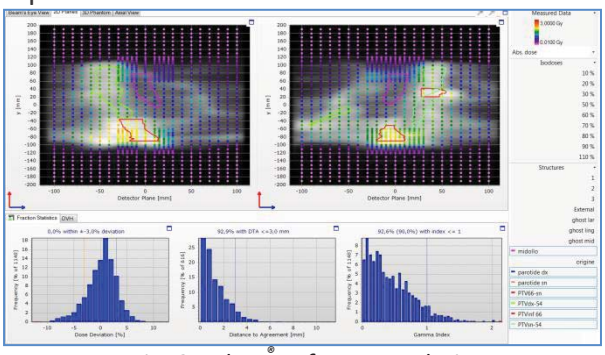


*Fig. 3 Delta4® software analysis*

Furthermore because the software shows the matrix of $\gamma$ statistics points (blue pass ($\gamma$ <1) and red fall ($\gamma$ >1)), it was also possible to investigate a plan respect the position of the “red points” and the organ at risk.

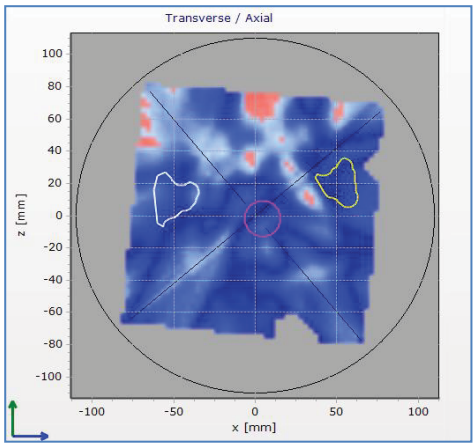



*Fig. 4a Example of $\gamma$ matrix in axial plan*

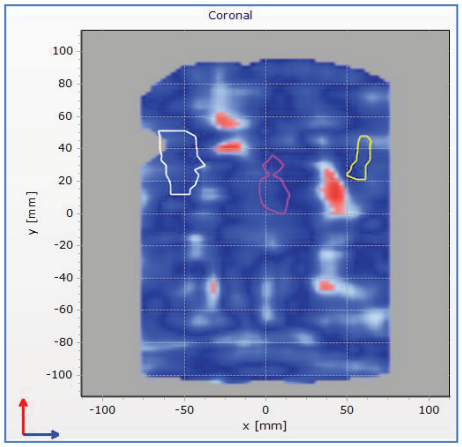



*Fig.4b Example of $\gamma$ matrix in coronal plan*

## Discussions and Conclusions

Verification of a planned dose distribution is a complex and time consuming procedure because all described parameters DTA, %DA and $\gamma$-index are very important and using only one of them is not enough to accept a treatment plan.

The plan must be investigated using every instrument and always taking in consideration the clinical meaning of eventual disagreement: for example a plan con $\gamma < 1$ in 90% of the analyzed points is not a good plan, but it is necessary verify the distribution of the points con $\gamma > 1$; if they are distant from target and organ at risk the plan can became acceptable.

Although Delta4 appears a straightforward device for measuring dose and allows measure in real time, it is a complex device and careful quality assurance before its use is therefore recommended.

## References

[1] Report AIFM "Intensity Modulated Radiation Therapy (IMRT): Dosimetric and Computational Aspect" N.3 (2006)

[2] James L Bedford, Young K Lee et al. "*Evaluation of the Delta4 phantom for IMRT and VMAT verification*" Phys. Med. Biol. 54 pp. 167-176; 2009

[3] B.E. Nelms, Jeff A. Simon " A survey on planar IMRT QA analysis", Journal of Applied Clinical Medical Physics, vol. 8, n.3 2007

[4] Judith Alvarez-Moret, Fabian Pohl et al *"Evaluation of volumetric modulated arc therapy (VMAT) with Oncentra MasterPlan® for the treatment of head and neck cancer" Radiation Oncology* 2010, 5:110

[5] T. Depuydt, A. Van Esch, and D.P. Huyskens. *"A quantitative evaluation of IMRT dose distributions: refinement and clinical assessment of the gamma evaluation"* Radiotherapy and Oncology, 62:309_319, 200