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Anatomy-corresponding method of IMRT verification

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ABSTRACT

Background: During a proper execution of dMLC plans, there occurs an undesired but frequent effect of the dose locally accumulated by tissue being significantly different than expected. The conventional dosimetric QA procedures give only a partial picture of the quality of IMRT treatment, because their solely quantitative outcomes usually correspond more to the total area of the detector than the actually irradiated volume.

Aim: The aim of this investigation was to develop a procedure of dynamic plans verification which would be able to visualize the potential anomalies of dose distribution and specify which tissue they exactly refer to.

Materials & methods: The paper presents a method discovered and clinically examined in our department. It is based on a Gamma Evaluation concept and allows accurate localization of deviations between predicted and acquired dose distributions, which were registered by portal as well as film dosimetry. All the calculations were performed on the self-made software GammaEval, the γ-images (2-dimensional distribution of γ-values) and γ-histograms were created as quantitative outcomes of verification.

Results: Over 150 maps of dose distribution have been analyzed and the cross-examination of the gamma images with DRRs was performed.

Conclusions: It seems, that the complex monitoring of treatment would be possible owing to the images obtained as a cross-examination of γ-images and corresponding DRRs.

1. Background

Although the IMRT was first implemented into the clinical practise several years ago and many papers have ever since been published on dynamic plans verification, it is still unclear why the local dose deviations between predicted and acquired dose distribution are observed.[1] It is believed that only the pre-treatment control of actually generated fluence is able to provide essential information about the quality of irradiation. Usually, it is limited to dosimetric verification which is typically performed using the gamma evaluation method.[2–4] As a result of the comparison between the acquired dose distribution and the predicted one, the matrix of $\gamma(\vec{r})$ is obtained. The measurement point $\vec{r}$ passes the criteria of correctness if $\gamma(\vec{r}) \leq 1$. A quantitative estimation of dose delivery is possible owing to γ-histograms which combine the information about a γ-index value with that of the area of corresponding part of the field.[5,6] In our previous paper,[7] we discussed the difference between the global gamma conception and its variety, local gamma, when the acceptable dose deviation (D_{max}) was proportional to the expected dose value $D(\vec{r}_c)$ for each element of the calculated dose matrix $\vec{r}_c$. The advantages and disadvantages of both approaches have been presented.

Sometimes, quantitative outcomes of dynamic plans verification performed by commercial instruments (score, average

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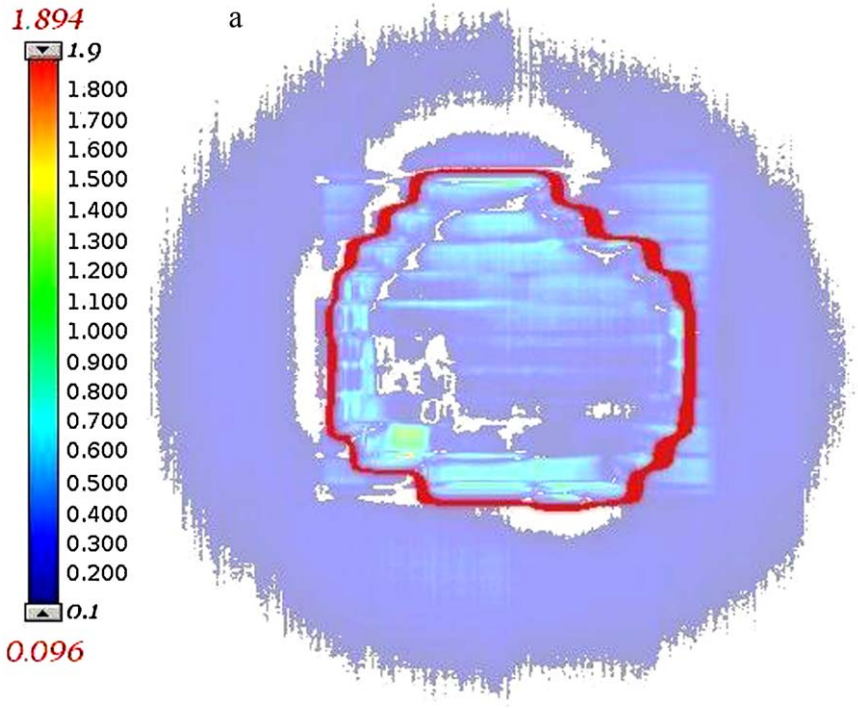

Label	Value
Dose difference criterion [%]	3.300000
DTA criterion [mm]	3.000000
Threshold (fraction of max. dose)	0.000000
Maximum gamma	1.894360
Average gamma	0.095687
Area gamma > 1.0 [%]	0.119453

Fig. 1 – Exemplary results of gamma evaluation obtained with Portal Dosimetry (Varian). (a) γ-Image and (b) quantitative outcomes.

gamma and γ-histograms) correspond to the total area of detector matrix or its regular, usually rectangular part, rather than the actually irradiated volume (field area). It makes the verification outputs hard to use and imprecise. See exemplary results presented in Fig. 1. The average gamma reported by the system for presented field is about 0.096, even though only a small number of points (marked in white colour) correspond to $\gamma < 0.096$. The underestimation of the parameter was possible, because the statistical report had been prepared for a total matrix of EPID and the unexposed points, which in fact do not belong to the field, had not been excluded. We believe that the key to obtain more reliable and useful outcomes of IMRT verification is to specify precisely the area of interest (define a border of therapeutic field).

The conventional solution based on the gamma approach shows the level of local dose variations only, which is certainly very important from the dosimetric point of view, but is in fact unable to localise irregularities or specify what kind of tissue they refer to. It will be demonstrated in this paper that the fusion of γ-image (graphical representation of γ-matrix) and corresponding DRR for each field is a sufficient procedure to estimate the process of specified organs irradiation (especially target and organs at risk) during IMRT treatment.

2. Aim

The aim of this investigation was to develop an IMRT verification procedure based on the Gamma Evaluation. When developed, the procedure could demonstrate how the differences in actual and expected dose distribution correspond to the target volume and organs at risk. Precise specification of therapeutic field borders makes the quantitative outcomes of verification more reliable.

3. Materials and methods

In our radiotherapy department the gamma evaluation method was adapted to dynamic plans verification in 2002. The IMRT treatment plans are prepared using the Eclipse treatment planning system (Varian Medical Systems Inc., Palo Alto, CA) and Varian linear accelerators (2300CD and 23Ex) with