The gamma evaluation method as a routine QA procedure of IMRT

Janusz WINIECKI, Tomasz MORGAŚ, Karolina MAJEWSKA, Barbara DRZEWIECKA

Received: 21.05.2009
Accepted: 31.10.2009
Subject: original article

Oncology Center
Bydgoszcz, Poland

Address for correspondence:
Mr Janusz Winiecki
Oncology Center,
Bydgoszcz, Poland
e-mail: janusz@co.bydgoszcz.pl

ABSTRACT

BACKGROUND: The conventional QA procedures dedicated to 3D CRT are unsatisfactory if the dMLC is in operation. In the case of IMRT not only should the dose on the beam axis, but also its distribution in the total plane perpendicular to the beam be taken under control. The comparison between the predicted and the observed fluence can be achieved using the gamma method. It takes into consideration the dose difference and the spatial displacement between analyzed points to provide a γ-index as a result of comparison.

AIM: The aim of the investigation was to develop the procedure of IMRT verification based on the gamma algorithm.

MATERIALS AND METHODS: 700 patients have been irradiated using IMRT since 2002. Over 1500 images recorded on the film and/or EPID have been analyzed with the help of self-made software. Histograms of γ-value and the γ- images have been created for each field. The fields have been classified depending on tumour location and the method of dose delivery, to obtain an average result for each class. We have performed a comparison of γ-histograms acquired with the help of different methods of recording.

RESULTS: We have observed a correlation between results of verification obtained with the help of the gamma algorithm and the method of intensity modulation.

CONCLUSION: Gamma evaluation allows one to find local hot-spots caused by irregularities in leaf motion or the tongue-and-groove effect.

KEY WORDS: IMRT, QA, Gamma evaluation, Gamma index, DTA

BACKGROUND

The concept of IMRT is an intentional diversification of dose distribution for the purpose of the best irradiation of the tumour body and simultaneous protection of the organs at risk [1]. The front of the IMRT beam in contrast with 3D CRT can be strongly undulated and the traditional QA procedures are not able to monitor the dose in the total plane perpendicular to the beam axis. There are several circumstances having an effect on the point dose really absorbed by tissue. The most important is the dynamic mode of MLC, which is required for dose diversification and pre-planned for intensity modulation. Of course, we cannot predict random failures and accidents which have great weight in the difference between expected and acquired dose. However, from time to time there are occurrences which are undesired but repetitive and influence the local dose accumulated by the absorbent. They take place during proper execution of the treatment plan, as has been carefully discussed by Ping Xia and Lynn J. Verhey [2].

The irradiation leakage through a slit between adjacent leaves can be only statistically taken into account, which may be done by a treatment planning system (TPS). We can

observe straight lines with high dose (hot-spots), whose escalation depends on the time of exposure. In order to reduce the dose leakage the border between leaves is in fact not a straight line [2].

Figure 1 presents the cross-section of the MLC and the intensity profile perpendicular to the direction of leaf motion. If the velocity of the two next leaves is very different, one can observe the "tongue and groove" effect. It occurs if significant dose gradients perpendicular to the leaf direction are expected. An example of this situation is presented in Fig. 2: the narrow region (white line) with dose much below the expected value. In the isocentre plane they are about 1 mm wide. Functional motions of irradiated tissues and ineffectiveness of patient immobilization usually reduce this undesired effect if the treatment consists of many fractions and the plan contains multiple gantry positions [3]. However, it is difficult to answer the question: Is the acquired dose distribution always really acceptable in the case of proper realization of the IMRT plan?

There have been several methods of IMRT verification proposed and strongly recommended in previous publications [4, 5, 6 ,7]. The investigators suggest detailed control of the IMRT plans, comparison of optimal distributions obtained by TPS and different methods of calculation. Chui et al. [8] present some useful tests which help to keep the MLC in a good condition, which is the key to proper IMRT execution. On the basis of the above-mentioned papers of Depuydt et al. [5] and Low et. al [7] we have developed our own procedure for clinical dosimetry of IMRT treatment. It takes advantage of the gamma evaluation method to compare predicted dose distributions with images recorded on the treatment unit.

AIM

The aim of the investigation was to develop an independent procedure of IMRT verification which would be performed on each treatment unit regardless of whether portal dosimetry is available or not. The procedure should be based on gamma algorithm and be viable in a clinical environment.

MATERIALS AND METHODS

In many radiotherapy departments the predicted dose distribution and the acquired one are compared using the gamma evaluation method. As a result of analysis the matrix of $\gamma(\vec{r}_c)$ is obtained. For each reference point

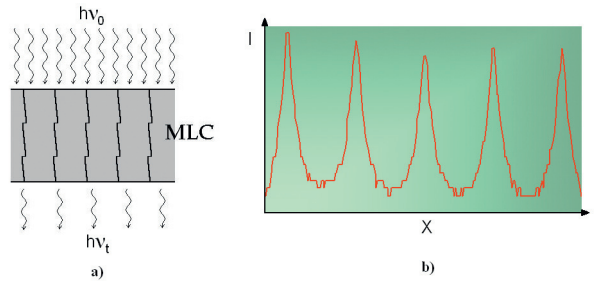

Fig. 1. The irradiation leakage through a slit between adjacent leaves of the collimator. a) the crosssection of the MLC ($h\nu_0$ – incident radiation, $h\nu_t$ – transmitted radiation), b) intensity profile perpendicular to the MLC direction

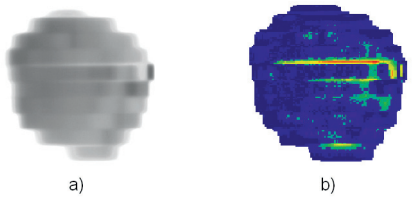

Fig. 2. The tongue-and-groove effect: a) dose distribution recorded on the film, b) corresponding γ-image

with respect to all measurement points $\vec{r}_m$ the series of $\gamma(\vec{r}_c, \vec{r}_m)$, values is calculated using formula (1):

$$\gamma(\vec{r}_c, \vec{r}_m) = \sqrt{\frac{|\vec{r}_c, \vec{r}_m|^2}{DTA^2} + \frac{|D(\vec{r}_m)-D(\vec{r}_c)|^2}{\Delta D^2}} \qquad (1)$$

where:

$|\vec{r}_c, \vec{r}_m|$ – distance between analyzed points,

$|D(\vec{r}_m)-D(\vec{r}_c)|$ – dose difference,

DTA, ΔD – scaling factors equal to 3 mm and 3.3% respectively.

As a final result $\gamma(\vec{r}_c)$ the minimum of $\gamma(\vec{r}_c, \vec{r}_m)$, is chosen for each $\vec{r}_c$.

In our cancer centre IMRT was started in 2002. In the beginning treatment plans were prepared using CadPlan/Helios, and recently Eclipse (Varian Medical Systems Inc, Palo Alto, CA). Varian Clinac 2300CD and 23Ex linear accelerators with Mark II 80MLC and