A Tool for Comparing Dose Distribution in 3D and IMRT Plans

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Abstract

In clinical practice, the choice which treatment plan is better is usually made in a very subjective manner. This decision is based on dose distribution in particular CT slices and on dose volume histograms (DVHs) for target volumes and organs at risk. The comparison tool (TCI') presented here is designed to give a simple answer as to which plan is better. The tool, TCI', is based on the ranking tool TCI [1]. The difference between the TCI and TCI' is that in TCI' the tolerance doses and adequate volume constraints are used and in TCI' arbitrary chosen test doses and average volumes (for these doses) calculated for all compared plans, are used.

Keywords: TCI, NTSI, NTSI', TCI', TCI'.

Introduction

Typically, comparison of treatment plans, performed by physicians, is based on dose volume histograms (DVH) and the dose distributions in particular CT slices. An index for evaluating plans was first proposed by Knöös et al. [2]. The conformity index (TCI) described there gives information on how well does the dose distribution fit the target volume. This index, however provides no information on the degree of sparing of normal tissue and organs at risk. This is a big disadvantage of the TCI index because the level of irradiation of normal tissue is a very important aspect of a treatment plan, which should be taken under consideration. A tool including both parameters, called the uncomplicated target conformity index (TCI'), was first presented by Miften et al. [1]. It consists of a TCI and normal tissue sparing index (NTSI). The NTSI evaluates plans by comparing dose distributions for normal tissues with clinically known dose-volume tolerance levels. If both compared plans fulfill tolerance levels they are assigned the same rank. In this paper, we propose an uncomplicated target conformity index (TCI') and also a normal tissue sparing index (NTSI') for comparing plans. The difference between NTSI and NTSI', is that in NTSI', instead of tolerance doses, (taken from clinical research [3, 4]) arbitrarily chosen test dose values (e.g. 5%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, 100% of the prescribed dose) and average volumes (for these doses) for all compared plans are used.

Experimental procedures

3D and IMRT plans were prepared for 5 patients with prostate cancer in order to verify the usefulness of TCI' performance against TCI'. During pre-simulation, the reproducibility of patient positioning was verified (maximum difference allowed: 3mm). Next, a CT examination was performed (helical technique, slices 3mm thick). The Gross Tumour Volume (GTV), Planning Target Volume (PTV), bladder and rectum outlines on CT slices were delineated by a radiotherapist. Conformal 3D and IMRT plans were prepared for 15 MV photon beam of a Clinac 2300C/D medical accelerator. The prescribed dose was 65Gy (2.6Gy per fraction). The 3D plan was prepared using 3 fields (0°, 90°, 270°) with suitable wedges. The fields were shaped with a MLC. The IMRT plan consisted of 5 fields – the gantry was set to: 0°, 75°, 135°, 225°, and 285°, or 45°, 105°, 180°, 255°, and 315°. For each field the
collimator rotation was set to 3°. The plans were calculated using the Varian Eclipse External Beam Planning System (v. 6.5) with the Helios optimization module.

The optimization procedure required two new structures to be defined: the overlap of PTV and rectum, and PTV without rectum. At the beginning, the optimization procedure was given the same priorities for all targets and organs at risk. After achieving some stability of optimization, the priority for targets was set higher. At the same time, the maximum dose within the body outline was not permitted to exceed 107%. This also required higher priority. After achieving satisfying dose distribution in targets, the dose in organs at risk was minimized. Minimum dose ($D_{\text{min}}$) for PTV was 95% of the therapeutic dose (62Gy) and maximum dose $D_{\text{max}}$ was 107% (70Gy). A situation in which maximum 0.05% of target volume received a dose less than $D_{\text{min}}$ was permitted. The penalty factors for plans were set at 10% for a dose 1% smaller than the dose specified as minimum dose, and for a dose 2% higher than the dose specified as maximum dose.

**Fig. 1.** Prostate case – dose-volume histograms (DVH) for rectum. About 11% of the rectum volume is included in the planning target volume (PTV)
Results

The doses for the rectum volume generally achieved the tolerance limit (Fig. 1). The constraint which occasionally was not achieved was that no more than 15% of a volume may receive a dose equal to or higher than 60Gy. This happened occasionally because in most cases over 10%–15% of the rectal volume was included in the PTV in which the minimum dose was set to 62Gy. In IMRT plans the TCI value (Tab. 1) was somewhat smaller than that for 3D plans, due to the doses smaller than $D_{min}$ occurring in some part of the PTV – the penalty values for these plans were equal 1 (i.e., no penalty) because the volume receiving a dose below $D_{min}$ was less than 0.05% of the total volume. The doses received by the bladder fulfilled constraints even better than the doses to rectum.

Comparison of indexes for 3D and IMRT plans (Tab. 1) indicates that in both techniques the requirements of dose distribution in target volume are achieved. Also, tolerance dose limits are not exceeded. The $TCI^+$ values for 3D and IMRT are similar even though the DVHs for organs at risk show better sparing in IMRT. This information is provided by the $TCI^+$.c.

Conclusions

The proposed $TCI^+$ index provides the user with a possibility to differentiate between two plans with respect to dose distribution in the normal tissue volume. Therefore it appears to be a better tool for comparing plans than the $TCI^+$ ranking tool which gives only information on meeting certain dose-volume constraints. The best solution is to use both tools independently to acquire more information. This may be of particular importance for organs which cannot receive dose higher than the tolerance dose (e.g. the spinal cord). For these organs a maximum dose should always be considered. This can be achieved by analyzing plan statistics or by calculating the $NTSI$ index.

References