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On Usability of Gamma Criteria Distribution for Evaluation of field-in-field Treatment Plans in Conformal Radiotherapy

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I. Introduction

Hard, dynamic or virtual wedges are often used in conformal radiation therapy to reduce dose inhomogeneity within the target volume. There are restrictions exist in using such field modifiers for large fields due to technical peculiarities of the treatment machine. Field-in-field (FIF) manual segmentation, where one or more subfields are used to achieve dose homogeneity, could solve this problem, but such technique needs to be evaluated and verified first. FIF technique is based on intensity modulated radiation therapy (IMRT) principle, except that the intensity modulation is done manually using direct planning. The aim of this article is to determine whether the gamma criterion evaluation principle is suitable for FIF plans verification. [1,2]

II. Materials and methods

A. Detector and phantom set up

Measurements were made, using phantom, composed of the water equivalent 1cm thick PMMA slabs and IBA I'mRT Matrixx pixel ionization chambers detector array. 10 PMMA plates was paced on the array to form 10 cm thick build-up layer, while 5 plates was placed under detector to provide 5 cm thick backscattering layer.

B. Phantom CT data acquisition and treatment planning

Treatment plans were based on the anterior – posterior (AP) rectangular isocentric field. The size of the field was 17 x 12 cm. For this field 70 monitor units (MU) were prescribed. For each plan base field was copied and additional segmented field was added to the base field to create FIF plan. Segment fields were rectangular, AP aligned and isocentric, with a center aligned with the center of the base field, sized 5 x 12 cm, 6 x 8,5 cm and 3 x 4,3 cm were used (f.v.).

C. Field distortion modeling and measurements

To simulate patient misalignment / movement and model field distortion, segment fields was shifted in 1 mm steps in superior, inferior, lateral left and lateral right direction up to distance of 10 mm.

D. Data analysis

Measured dose distributions were compared with the reference, simulated by TPC, using gamma criteria. The dose differences, distances-to-agreement (DTA) and corresponding gamma distributions were evaluated using Omni PRO-I'mRT software. As the acceptance criteria for individual point, $\Delta DM=3\%$ dose-difference and $\Delta dM=3$ mm DTA were used [Fig.2]. For two dose distributions to be considered equal, 95% of all pixels should be within this criterion. [4] The chosen criteria are those routinely used in clinic for verification of the IMRT plans.

III. Results and discussion

The longitudinal shifts of the largest segment field in the direction of the field's longest side show steeper decrease in the number of "passed" pixels. Nevertheless, even as large shifts as 10 mm for the 6 x 8,5 cm and 3 x 4,3 cm segments do not lead to the percentage drop below 95% threshold. For the largest segment 5 x 12 cm, 8 mm shift required to decrease percentage of passed pixels below 95%, to the 94,66% and 94,42%. for superior and inferior shifts, correspondingly. The same shifts were analyzed using only DTA criterion, i.e. pixel form the reference distribution pass the criterion, if there is at least one pixel at the distance less then DTA. The DTA based evaluations of the number of passed pixels for lateral and longitudinal shifts are shown in Figure 5 and Figure 6, respectively. The results show that for FIF technique, the criteria, based on the distance discrepancy is more sensitive. The 95% threshold was reached for 5 x 12 cm and 6 x 8,5 cm at lateral and longitudinal shifts of 4 mm. Besides, for the small perimeter field, this method fail to detect discrepancies in the dose distributions for lateral shifts more then 10 mm and for superior – inferior shifts up to 8 mm. The reason of the poor performance of gamma criteria and DTA criteria seems to be entirely geometrical. FIF technique is characterized large areas of flat dose distributions. In such a case, both gamma and DTA criteria will indicate difference at the edges of segment field. For the segments of small perimeter, the number of pixels affected by shift may just be smaller, then 5%.

IV. Conclusions

For small area segments, even the large misalignment of the fields did not lead to significant changes of the percentage of failed pixels. Gamma criterion with dose difference 3%, and DTA 3mm showed poor sensitivity to the misalignment for field-in-field plan evaluations due to small segments perimeters and relatively small ratio between numbers of pixels in field versus number of pixels in shifted area. Even clinically significant shifts of 10 mm pass the 95% threshold level. 95% criteria should not be used at all for comparison of dose distribution in field in field conformal radiotherapy and other numerical criterion has to be developed.

V. References

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