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Reconstruction of Dose Calculation on CT-Image from Dose Distribution in Water Phantom

Manabu Mizota, Tatsuaki Kanai, [1]Takashi Akagi, [2]Haruo Yamashita, Munefumi Shimbo, Yasuyuki Futami and Masahiro Endo

NIRS, [1]Hyogo Pref. Hospital Bu., [2]Shizuoka Pref. Gov.

INTRODUCTION

While a radiotherapy treatment planning (RTP) system intends to make a desired dose distribution in a patient, the corresponding irradiation system involves various devices in realizing the distribution, such as wobble magnets, a scatterer, a range shifter, collimators and bolus. The accuracy of the whole system is demonstrated by comparing dose calculation with measured dose distribution. The dose distribution realized by the irradiation system cannot be measured in patient body but in water phantom. On the other hand, RTP system provides us the dose distribution on the CT images of the patient. For the comparison of the two dose distributions, it is necessary to convert the calculated distributions in a patient to those in water phantom or to convert the measured distributions to those on the CT image. We developed the conversion tools for these comparisons and this procedure has been tested in heavy-ion therapeutic beam irradiation using HIMAC treatment system.

METHOD

According to a treatment plan with regard to CT-image of a patient, the therapeutic beam is configured by accelerator, collimators, filters, and so on, through the parameters made by the RTP system in order to give the ideal dose distribution. The realized dose distribution for the area of interest is measured in a water phantom using a scanning thimble type chamber or in the air with a range shifter. For reducing the measuring time, a multi-layer ionization chamber is also used, which acquires a depth dose distribution at one time. A microcomputer is used to record and to calibrate dose data.

Two modes of conversion calculation are carried out to make an inspection or comparison for the dose distribution.

(1) Conversion to the distribution in water phantom: Clinical dose distributions are normally calculated and beam configuration is made, using the ray-tracing parallel beam algorithm by our RTP system. Then, with this beam configuration, dose calculation is made for numerical water phantom.

(2) Conversion to the distribution in patient body: While measured dose distribution is stored in the array of a computer, the block of CT value is processed by translation and rotations to cut out the set of value on the same plane as the plane of the measurement. With these values, water equivalent depth to each point on the plane of CT image from a beam source is calculated, individually. Then, an expected dose is derived by look-up in the measured data array according to the water equivalent depth and multiplied a factor from a beam divergence effect that depends on the path length of the geometry.

All these dose distributions are normalized to the maximum dose in the individual plane. Once being calculated, dose distribution information can be easily handled to make a comparison or to display in any form, such as color-coded isodose lines or furthermore overlaid on the 2-D gray-scale image that corresponds to anatomical information.

RESULTS

For one example, isodose profiles reconstructed from the measured data using above mentioned conversion(2) are illustrated in Fig.1. In this case, irradiation from left side on this paper is separated to two fields by a block for an eye protection. As the dose distribution information can be seen on 2-D gray-scale images of the patient's anatomy, verification of the irradiation system could be made in a very straightforward way.

Figure 1. Reconstructed isodose display on a CT image
Blue line represents 50% dose of maximum. Light blue, yellowish green, yellow, red represent 80%, 85%, 90% and 95%, respectively.

DISCUSSION

Quantitative comparison of dose distribution calculated by RTP and that of measurements can be performed in above mentioned two modes. These conversions validate the irradiation system including dose calculation algorithm of the RTP. A large difference between two distributions should not be accepted. In each mode, dose difference display can be created, that is, the subtraction of a percent dose from the other one, point by point. The graphic methods allow the display of discrepancies in many formats and also highlight the area that fail some criteria.

In both mode, one can easily find out what part of the distribution make difference and its magnitude. Depending on the area, the cause of the discrepancy could be guessed with ease. They are, for example, attributed to misalignment of irradiation devices, bolus error, or calculation algorithm error.

Especially in the mode of reconstruction on CT image, evaluation of the dose distribution or difference distribution could be made with adding therapeutic point of view. When the target volume is also shown sticking through the isodose surface, for example, one can easily see where the regions of target volume underdose are located and that the dose out of the target gives bad effect or not. Moreover, when the discrepancies are somewhat inevitable, this information would give us a judgement to go on irradiation therapy of this plan or try to make another planning with varying target volume or spatial margins, etc.

CONCLUSION

Coupled with a rapid dosimetry of 2-D or 3-D, the dose distributions displayed with respect to the anatomy expressed by the CT image bring useful information to the planner and physician in analyzing the cause of the discrepancy from planned irradiation. In addition, presentations or comparisons of distributions would give helpful assistance particularly in QA of the irradiation system or a verification of the RTP system.