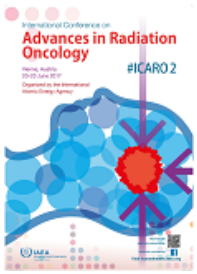

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Dosimetric evaluation of dose distributions delivered to an in-house developed respiratory chest phantom

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Introduction

In radiotherapy, intra-fractional movement of organs can cause important discrepancies between planned and delivered dose distributions. The magnitude of the discrepancy will depend on several factors, including the range and direction of organ movement, the margins of the planned distribution, the algorithm used for the dose calculation and the type of treatment, among others. The photon radiotherapy treatments of tumors located in the lungs are therefore especially prone to face this challenge. There are several techniques that have been clinically implemented to deal with the issue of organ motion during the delivery of the treatment; respiratory-gating is one of those.

Objectives

The purpose of the study was to assess the impact of the respiratory motion on the delivered dose distributions to an in-house developed respiratory phantom by using different dosimetric systems, planning strategies and delivery conditions, including respiratory-gating.

Materials and methods

The chest phantom consisted in a rigid plastic frame with two cavities simulating the lungs mounted in a platform which allowed the installation of motor powered mechanical systems that moved a simulated tumor inside the lung and a vertical platform above the surface of the phantom. The simulated tumor target was a 4 cm diameter sphere made of plastic. This was able to move in different directions (longitudinal and rotational) for user defined waveforms, as it was connected through an insert to the external mechanical system. The platform simulating the chest surface, where markers are placed to act as surrogates of tumor motion, moved vertically also following a predefined waveform. The movement of the target and the platform was computer controlled by a program developed in LabView, allowing the user to control the waveform parameters and correlation between the surface and tumor motion. Inside the tumor, it was possible to measure the delivered dose using different dosimetric systems: a photon diode, TLDs and radiochromic films. The phantom was scanned and different treatment plans were elaborated. The plans included different strategies for motion management: no motion consideration, increased margins and respiratory gating. The dose was computed using pencil beam, collapsed cone and Monte Carlo based algorithms and then delivered to the phantom in static and dynamic modes. The dose calculated by the treatment planning system for the target was compared with measurements made by the detectors inside the tumor and evaluated.

Results

It was found that the abrupt changes in density between the target material and the air surrounding it made it very challenging for the calculation algorithm to reproduce the delivered dose, generating values that overestimated the dose within the target, even in static conditions. The differences were up to 8% in the center of the target, where the discrepancies between algorithms were smaller compared to the borders of the target. Therefore for the rest of the study only Monte Carlo based calculations were used, as it was the only algorithm able to reproduce the delivered dose in the experimental conditions. As expected, important differences from the prescribed dose were found if no motion compensation strategy was applied (up to 20%) for a longitudinal movement of 8 mm range. For the gated-therapy case, a very good agreement between measured and planned distributions was found (within 2%). The discrepancies for the gated case indicated that its implementation would not increase the uncertainty in the delivered dose, as the differences between measurements and calculation for a static plan (no motion management) and delivery were of the same order.

Conclusions

The study confirms the importance of using an adequate dose calculation algorithm when dose calculations are performed in the presence of inhomogeneities where there are abrupt changes of electron densities. Otherwise, the dose can be overestimated for the target and underestimated in the surrounding healthy tissues, in lung tumor cases. The phantom was useful to reproduce clinically relevant conditions and to evaluate the effect of intra-fractional target motion. Its design would additionally allow for the estimation of dose uncertainties related to the implementation of other motion management techniques such as tracking and respiratory gating using only an external surrogate, such as a reflective marker or a pressure belt.

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