Calculation of uncertainties in brachytherapy treatment planning

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Introduction

We strongly believe that recent concepts of external radiotherapy such as image guidance and adaptive radiotherapy should also be taken into consideration in modern brachytherapy. In daily HDR treatments, there is a need to know what the patient (i.e. his geometry, anatomy, and constitution) and the source (i.e. the catheter position and the current source characteristics, mainly its position) are doing. The knowledge of all these items is important for a comprehensive quality assurance (QA).
On the other hand, it is foreseen that QA applications such as checking every individual catheter position is very time consuming and thus the question arises whether or not there are more efficient approaches which still cover the main aims of the QA applications. One idea is to use probability distributions of errors. By this means, the probability distributions of errors are used to define a priority list of issues to be checked. For instance, if a clinical brachytherapy application consists of 10 interstitially applied catheters, the "most critical" ones need to be checked first.
In this work, as a first step towards an efficient QA procedure in brachytherapy, we developed a method which estimates the dosimetric uncertainties for a patient specific treatment plan.

Material and Methods

Three different sources of errors in brachytherapy treatment planning are considered in this study: Errors due to the limited CT slice thickness [1], errors due to limited accuracy of the spatial reconstruction of catheters and the corresponding dwell positions [2], and errors due to inter-fraction motion of the catheters [3]. A software tool (IDL, Interactive Data Language) was developed to investigate the corresponding probability distributions of these errors. These distributions were used to estimate their impact on the dose distribution for a specific treatment plan. The quality assurance procedure consists of the quantitative comparison between the original dose distribution and the dose distribution calculated using the error probability distributions.

Results

Dosimetric uncertainties of academic and clinical treatment plans indicate that the limited accuracy of the catheter reconstruction is most critical while the limited CT slice thickness mainly affects the dose distribution at locations near the tip or the connector end of the catheter. The dosimetric uncertainties depend on the magnitude of the errors and the relative weights of the different sources of errors. As an example, the dosimetric impact of a 1 mm error in catheter reconstruction for a head and neck tumor is in the order of 5% for the PTV.

Discussion

In this work, a method for the estimation of dosimetric uncertainties for a brachytherapy treatment plan was developed. On a patient specific basis, different sources of errors and their particular dosimetric impact are analyzed. Consequently, by identifying and quantifying the sources of errors for an individual treatment plan, the method can be applied for highly efficient patient specific quality assurance procedures for interstitial brachytherapy.

References

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