PhD thesis title: Use of Monte Carlo methods in characterizing the heterogeneities and their radiobiological impacts in brachytherapy

(Original French Title: L'utilisation des méthodes Monte Carlo pour la caractérisation des hétérogénéités et de leurs conséquences radiobiologiques en curiethérapie)

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Abstract

Current clinical algorithms for dosimetry in brachytherapy are generally based on the American Association of Physicists in Medicine (AAPM) TG 43 recommendations. These algorithms systematically neglect medium heterogeneities by using water in dose calculations. Therefore, the density and the chemical composition of tissues are not considered in dose calculations. Moreover, brachytherapy seeds are made of high atomic number materials. Hence the water medium approximation makes the current dosimetry algorithms neglect the effect of the interseed attenuation in dose calculations.

The purpose of this work is to study the heterogeneities in low dose rate (LDR) brachytherapy and to quantify their effect on dosimetry as well as on radiobiological evaluation of treatments. A dose calculation platform is designed using Monte Carlo calculation methods. This platform is able to consider and to reproduce implant geometries in detail using the DICOM RT standard. In the first part of this work, the interseed attenuation is studied from the seed design and composition point of view. We saw that the interseed attenuation changes depending on the LDR seed design. Then the sensitivity of dose distributions to tissue composition is shown for breast LDR brachytherapy. The first part of this thesis ends with the proposal of different tissue segmentation methods to be used in breast brachytherapy. The advantages and the limitation of each are investigated. In the second part of this project, we studied the effects the heterogeneities on radiobiological evaluation of brachytherapy treatments.

We investigated how the biological effectiveness may be over- or under-estimated if the heterogeneities are neglected in the calculations. Finally, equipped with tools for accurately evaluating the radiobiological efficiencies of brachytherapy, we proposed a recalculation of the radiosensitivity parameter for prostate cancer, α/β. We proved how, by considering different levels of heterogeneities, the evaluation of the a/b ratio for prostate cancer can change.

References to author publications that relate specifically to the dissertation:

1. H. Afsharpour, M. D'Amours, B. Coté, J-F. Carrier, F. Verhaegen and L. Beaulieu. 'A Monte Carlo study of seed design on the interseed attenuation in permanent prostate implants'. Medical Physics 35 (8) 2008 3671-3681

2. H. Afsharpour, J-P. Pignol, B. Keller, J-F. Carrier, B. Reniers, F. Verhaegen and L. Beaulieu . 'Influence of breast composition and interseed attenuation in dose calculations for post- implant assessment of permanent breast 103Pd seed implant'. Physics in Medicine and Biology 55 (16) 2010 4547-4561

3. H. Afsharpour, G. Landry, B. Reniers, J-P. Pignol, L. Beaulieu and F. Verhaegen. 'Tissue modeling schemes in low energy breast brachytherapy'. Physics in Medicine and Biology 56 (22) 2011 7045-7060

4. H. Afsharpour, B. Reniers, G. Landry, J-P. Pignol, B. Keller, F. Verhaegen and L. Beaulieu. 'Consequences of dose heterogeneity on biological efficiency of 103Pd permanent breast seed implants'. Physics in Medicine and Biology 57 (3) 2012 809-823