Improving radiotherapy treatment for left-sided breast cancer

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Chapter 1 introduces a general overview of the thesis and the topics of study. A brief history of breast cancer and its treatment are provided. The evidence and rationale for adjuvant breast radiotherapy (RT) are discussed. Left-sided breast cancer patients with large irradiated heart volumes are identified as patients at high risk for late cardiac mortality. Given that adjuvant breast RT is associated with cardiovascular events, improving breast radiotherapy would be of particular concern and benefit in this patient subset.

Chapter 2 evaluates the variant dosimetric effects of contour changes and tissue inhomogeneities, as a function of setup uncertainty, for a “worst-case” lung cancer patient. Usually, the planned dose distribution is convolved with a probability function, assuming an invariant (i.e. rigid body) dose distribution. However, such an assumption necessarily neglects the variant dosimetric effects of varying contours and tissue inhomogeneities during the convolution itself. The consequences of invariant and variant effects are examined and compared. The results suggest that variant effects are negligible as long as the setup uncertainty probability convolution function is symmetrical and that rigid body dose distributions, although technically incorrect, are sufficiently accurate in practice to be used in most convolutions.

Chapter 3 compares non-uniform beam (intensity modulation radiotherapy, IMRT) against uniform beam (wide split tangents) and mixed modality (oblique electrons) treatment plans irradiating the left breast and internal mammary lymph node chain (IMC). All plans are normalized to the mean breast dose to allow an unbiased comparison between the estimated complication rates of the organs at risk (OR). The IMRT plan provides the best compromise in terms of OR sparing and target coverage. The wide split tangent plan tends to overdose the heart while the oblique electron plan tends to underdose the IMC.

Chapter 4 compares the reduction in cardiac and pulmonary complication rates between wedged rectangular, wedged conformal and intensity modulated beam plans for the left breast. All plans are normalized to the mean target dose. Modifying the treatment technique, all else being equal, from rectangular to conformal to intensity modulated beams, reduces the cardiac complication rates, on average, from 5.9% to 4.0% to 2.0%, respectively.

Chapter 5 evaluates the optimal orientation for uniform beams using target-eye-view (TEV) maps. TEV maps evaluate every beam’s-eye view exhaustively and plot the results as a Mercator projection. In general, the best beam directions tend to avoid the more critical structures (such as lens and optic apparatus). However, TEV maps are limited to single, conformal, uniform beams so these results cannot be extrapolated directly to non-uniform beams.

Chapter 6 determines the optimal 2-beam orientation for heart sparing in left-sided breast cancer patients for uniform and non-uniform treatment techniques. An exhaustive search through all axial 2-beam combinations, discretized into 5° increments is performed. The results suggest that optimal uniform and non-uniform beam orientation
class solutions exist, depending on: VOI geometry, VOI constraints and treatment technique. Optimal uniform 2-beam orientations for the breast consist of opposing tangential medial and lateral beams (i.e. ~185°). Optimal non-uniform 2-beam orientations for left-sided breast cancers are bimodal, containing hinge angles around 160° and 210°. Non-uniform beam techniques are less sensitive to beam orientation compared to uniform beam techniques and result in significantly improved heart sparing but at a cost of slightly compromised PTV coverage.

Chapter 7 describes a class solution treatment technique to spare late cardiac complications for left-sided breast cancer patients using simplified IMRT with predefined segments. Optimal beam orientations defined for uniform (i.e. ~185°) and non-uniform (i.e. 210°) techniques were taken from the previous study. Five treatment techniques are compared: 3DCRT with optimal uniform beam orientations, full IMRT with optimal uniform beam orientations, simplified IMRT with optimal uniform beam orientations, full IMRT with optimal non-uniform beam orientations and simplified IMRT with optimal non-uniform beam orientations (i.e. class solution). For optimal (i.e. tangential) uniform 2-beam orientations, significant heart sparing is possible with the addition of intensity modulation but at the expense of worsening target coverage. Simplified IMRT can, for all intents, be substituted for full IMRT with tangential beam orientations. Applying more optimal non-uniform beam orientations improves PTV coverage while maintaining significant heart sparing but increases the PTV dose heterogeneity.

Chapter 8 discusses the study ramifications, speculates of potential future directions and summarizes all the studies.