Radiobiological Comparison of Single and Dual-Isotope Prostate Seed Implants

Purpose:
Several isotopes are available for low dose-rate brachytherapy of the prostate. Cancer tends to develop in foci within the prostate. While most implants currently use a single isotope, it may be advantageous to use short-lived isotopes in disease foci and longer-lived isotopes elsewhere in the prostate. However, even when the prostate is treated as homogeneous, the use of dual-isotope implants may yield an advantageous combination of characteristics such as half-life and relative biological effectiveness.

However, the use of dual-isotope implants complicates treatment planning and quality assurance. Do the benefits of dual-isotope implants outweigh the added difficulty? The goal of this work was to use a linear-quadratic model to compare single and dual-isotope implants.

Methods:
Ten patients were evaluated in this study. For each patient, five treatment plans were created in addition to the clinical treatment plan using single or dual-isotope combinations of $^{125}$I, $^{103}$Pd and $^{131}$Cs. For the dual-isotope implants, a separate plan had to be made for each isotope and combined. These individual plans used a prescription dose one-half that used in respective single-isotope implants. Before the plans were combined they were inspected to ensure no seed positions overlapped between plans. For each plan the prostate, urethra, rectum and bladder were contoured by a physician.

The biologically effective dose was used to determine the tumor control probability and normal tissue complication probabilities for each plan. Each plan was evaluated using favorable, intermediate and unfavorable radiobiological parameters, as suggested by King et al. The tumor was assumed to have uniform favorability. The results of the radiobiological analysis were used to compare the single and dual-isotope treatment plans.

Results:
Figure 1 shows the results of the single-isotope implants. Figure 2 shows the results of the dual-isotope implants. Iodine-125-only implants were seen to be most affected by changes in tumor aggressiveness. Significant differences in organ response probabilities were seen at common prescription dose levels. It was recognized that these differences were likely a result of suboptimal initial seed strengths.

By performing a simple optimization, where only the initial seed strengths were varied, the dose level was adjusted to maximize the complication-free tumor control probability ($P+$). After this adjustment the differences between isotope combinations were minimal. This result was true even for unfavorable tumors. Figure 2 shows that for dual-isotope implants there is no best relative weighting of isotopes. Rather, a broad plateau of combination producing similar results. The results of this work indicate that there is no discernible benefit to use dual-isotope implants when the tumor is treated as homogeneous, as is commonly assumed. This does not imply that benefit could not be gained by dual-isotope implants if one is able to know the distribution of disease within the tumor, by some advanced imaging technique.
Figure 1. Response curves as a function of initial seed strength for single-isotope plans. The black vertical line shows the original seed strength. The red vertical line shows the optimal seed strength.

Figure 2. $P_+$ as a function of initial seed strength for the dual-isotope combinations.

Conclusion:
The objective of this work was to perform a radiobiologically based comparison of single and dual-isotope prostate seed implant plans. For all isotope combinations, the plans were improved by varying the initial seed strength. For the minimally-optimized treatment plans, no substantial differences in predicted treatment outcomes were seen among the different isotope combinations. No additional benefit, in terms of improved control or reduced toxicity, was expected with the use of dual-isotope implants.