Title: An examination of needle deflection in high dose rate prostate cancer brachytherapy

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Structured Abstract:

Introduction: High dose rate (HDR) brachytherapy (BT) is a common treatment technique for prostate cancer that involves irradiating the entire prostate by passing a high activity radioactive source through multiple hollow needles inserted within the prostate. Typically, a whole-gland approach is used where the goal is to deliver as uniform a dose as possible to the entire prostate, with a maximum deliverable dose limited by toxicities to nearby organs at risk. To improve tumour control while maintaining acceptable rates of toxicity, tumour-targeted HDR-BT has been proposed to escalate dose to the intra-prostatic lesion, which is the most common site of local prostate cancer recurrence. In this scenario, accurate and reliable needle placement is critical; however, ideal needle placement within the prostate is often hampered by unintended needle deflection, thus limiting how well a specific region within the prostate can be targeted. The purpose of this work, therefore, is to examine the magnitude and direction of needle deflection in HDR-BT procedures.

Methods: Post needle implant 3D ultrasound images have been taken for 11 prostate cancer patients who underwent HDR-BT, giving the final inserted position for a total of 173 needles. A medical physicist manually segmented the needles, thus determining the actual needle tip and trajectory. Needle deflection was quantified by assuming the radiation oncologist intended to insert the needle perpendicular to the template and at the left-right (X) and anterior-posterior (Y) position of the needle's associated template hole. Any deviation from this assumed path was characterized as a needle deflection. Tip deflection was calculated as the Euclidian distance between the intended and the actual needle tip, while trajectory deflection was calculated as the angle between the intended and actual needle trajectory. Correlation between insertion depth and tip and trajectory deflection was also determined using the Pearson correlation coefficient.

Results: Mean tip and trajectory deflection, plus or minus standard deviation, was 6 ± 3 mm and 2 ± 1^{o} respectively. There was a statistically significant correlation between insertion depth and tip deflection ($r=0.247$, $r^2=0.061$, $p < .05$), but no significant correlation was observed between insertion depth and trajectory deflection ($r=0.061$, $r^2=0.004$, p=ns). Qualitatively, the majority of needles bent away from the prostate, with increased deflection observed near the edge of the prostate.

Discussion: We present an examination of needle deflection in HDR-BT procedures. Future work includes looking at the direction and magnitude of deflection in different regions of the prostate. We plan on using this information to develop a predictive algorithm which will allow us to determine the optimal template hole to target a given region of the prostate. This will be especially useful in tumour-targeted HDR-BT.