Highlight of Papers

A Novel Direction Modulated Brachytherapy Technique for Urethra Sparing in High-Dose-Rate Brachytherapy for Prostate CancerAll titles in DIN Pro (Condensed)

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What was your motivation for initiating this study?
Urethral stricture, a genitourinary radiation-related complication, can develop in prostate cancer patients after high-dose-rate (HDR) brachytherapy treatment. This issue predominantly manifests in the pre-apical section of the urethra and is strongly correlated with elevated doses to the urethra. To tackle this challenge, several intensity-modulated brachytherapy (IMBT) strategies have been introduced, which are aimed at diminishing the urethral dose without compromising prostate coverage. All such solutions, proposed thus far, are performed with HDR sources that can be dynamically rotated inside partially shielded catheters through the use of an additional, dedicated, treatment delivery apparatus[1]. Despite promising results, clinical implementation of these techniques is challenging since an additional treatment delivery apparatus is required, which must sync with the remote afterloader, to manage the dwell loading patterns accurately in combination with the dynamic motion of the needles. Furthermore, it is proposed that this technique be performed with non-conventional HDR sources such as ^{153}Gd or ^{169}Yb, which means that integration of this technique with current commercially available remote afterloader platforms becomes an additional challenge[1]. These difficulties prompted us to design a unique but practical IMBT solution, termed Direction Modulation Brachytherapy (DMBT), which requires the use of no moving parts during treatment delivery (thus excluding the need for additional treatment delivery apparatus) and uses the ubiquitous ^{192}Ir HDR sources for straightforward integration with the available remote afterloader(s).

What were the main challenges during the work?
We had two main challenges. The first was to see whether the DMBT concept was translatable to the current clinical workflow. The main requirement was to identify the needles that were near the urethra and to replace them with DMBT needles. Then, the question was whether implementation of this technique would leave the target coverage unaltered, measured through factors such as the minimum dose required to cover 100% of the prostate volume (D_{100}) and the percentage of the prostate receiving 90% of the prescribed dose (V_{90}). To answer this question, we reviewed six previously treated patients who had different prostate sizes, anatomy, and numbers of needles used, and assessed the dose-volume histogram (DVH) criteria for the prostate and urethra. The second challenge was the quantification of the sensitivity of the results when needle-positioning uncertainty was incorporated. To quantify this, a maximum $\pm 10^{o}$ of angular positioning offsets were simulated for the DMBT needles and the changing DVH metrics were reviewed.

What are the most important findings of your study?

Our study showed that when the same DVH planning constraints were used as had been set in the original plans, the DMBT plans reduced the maximum urethral dose by 10.3% ± 5.6% and 8.1% ± 5.0% for a 0 mm margin in the planning target volume (PTV) and by 17.7% ± 14.2% and 16.6% ± 13.3% for 2 mm PTV margins, for the VariSource and GammaMedplus ^{192}Ir HDR sources, respectively. This was achieved while an equivalent V_{90} and D_{100} target coverage was maintained. Additionally, the uncertainty analysis revealed that the DMBT needle technique was very robust, such that absolute change in the prostate D_{100} and the urethra maximum dose (D_{max}), dose received by 0.1cm^3 of the target volume ($D_{0.1cm3}$), and the minimum dose required to cover 10% of the target volume (D_{10}) were on average 0.0% ± 0.0% (0.0% ± 0.0%), 0.2% ± 0.4% (0.0% ± 0.6%), 0.0% ± 0.1% (0.0% ± 0.3%), and 0.1% ± 0.1% (0.1% ± 0.2%) for the plans with 0 mm (2 mm) PTV margins, respectively.

What are the implications of this research?

The leverage of DMBT concept(s) as applied to prostate HDR brachytherapy is a promising way to reduce urethral dose and its related toxicity, without compromising target coverage. This technique is user-friendly, as the DMBT needles maintain the same dimensions and form factor, ensuring ease of insertion for physicians. Our research suggests that a limited number of DMBT needles positioned near the urethra can offer significant benefits without extending treatment duration or a need for extra, cumbersome equipment or software to modulate intensity. Treatment is also robust under rotational uncertainties. A few steps are now required to make this system a clinical reality, including the performance of a comprehensive treatment planning study with a broader patient selection and the fabrication of DMBT needle prototype(s) for dosimetric and other clinical end-to-end testing. We are confident of the feasibility of this approach and are directing our efforts towards its clinical implementation for the betterment of patient care.

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References

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