Towards MRI in Ultrasound-Guided High-Dose-Rate Prostate Brachytherapy: Mental Fusion vs Deformable Image Registration

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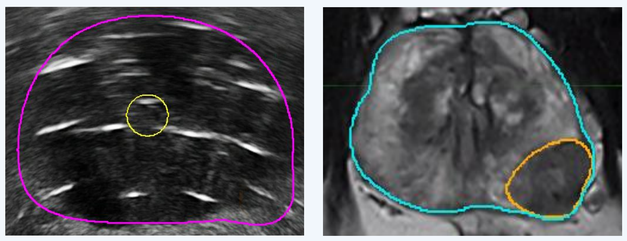
Introduction

- Transrectal ultrasound (US) is the primary modality for guidance & planning in prostate HDR-BT
- Unfortunately, the dominant intraprostatic lesion (DIL) is not visible in US images (left)
- In contrast, the DIL is clearly visible in magnetic resonance (MR) images (right)

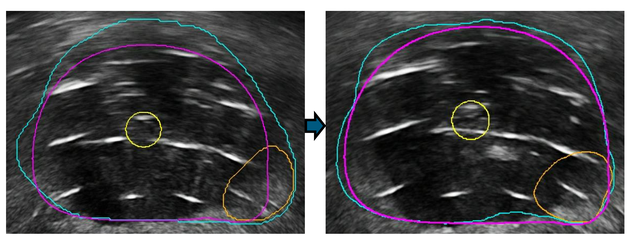


- While mental fusion of the MR-defined DIL to the US image is the simplest method to link the two image modalities, a deformable image registration approach may allow for more accuracy

Question: Is a mental fusion technique sufficient for DIL targeting?

Methods

- This study utilized retrospective imaging data for three prostate cancer patients who received HDR-BT
- Physician translated the MR-defined lesion from a pre-treatment MRI to the US space via mental fusion
- Retrospective MRI-to-US deformable image registration was performed using MIM Software Inc. tools as described below:
  1. Initial manual rigid (translation+rotation) alignment of US and MR images
  2. Automated surface-based prostate-to-prostate deformation of the MR image to the US space
  3. Translation of deformed MR lesion to US space



- Prospective validation for 1 salvage HDR-BT case
- Results evaluated using DVH analysis & Dice coeff.

Results

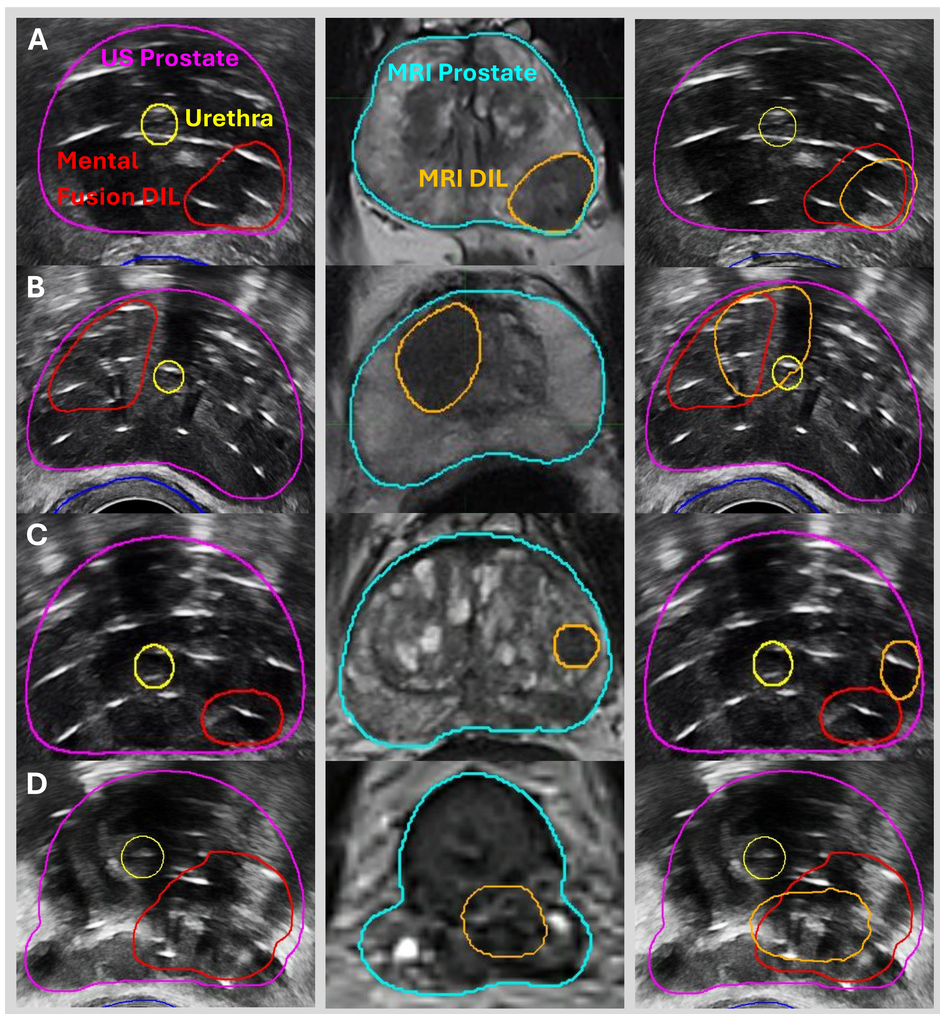


Figure 1. Three retrospective clinical cases (A, B, C) and one prospective case (D) showing an US image with mentally fused DIL (Left), pre-treatment MRI with defined DIL (Middle), and deformable image registration result with fused MRI DIL displayed on US (Right).

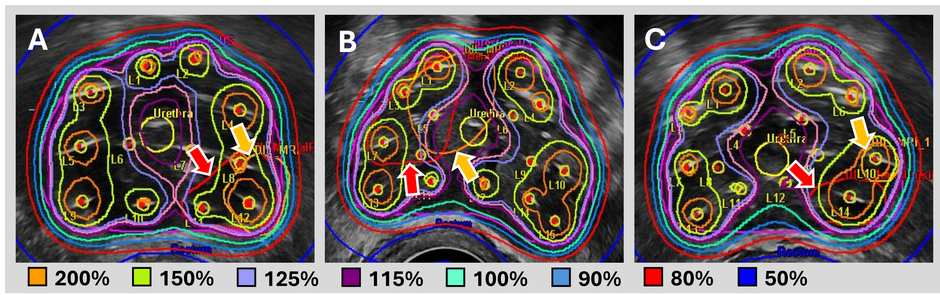


Figure 2. Isodose distributions for the same 3 retrospective clinical cases showing the clinical treatment plan recalculated with the mentally fused DIL (red arrows) and deformed MR-defined DIL (orange arrows) displayed on the ultrasound image.

- While the mental fusion and MR-defined DIL did not overlap for 1 case, the average Dice similarity coefficient was 0.40 ± 0.08 for the other two lesions
- For the same clinical plan, the average V100% for the DIL was 100% for the mental fusion and 98% for the deformably registered MR-defined lesion
- Average DIL D90% was 125% vs 119% for mental fusion vs MR-defined

Discussion

- MR-defined DIL contours were 45% smaller than their mental fusion counterparts, highlighting the more conservative mental fusion approach designed to ensure coverage despite decreased accuracy
- Interestingly, DIL V100% results show that a typical HDR-BT distribution is robust enough to ensure 100% isodose coverage regardless of this diminished DIL registration accuracy
  - This was true even when the mentally-fused and MR-defined DIL's did not overlap at all
- Beyond the 100% isodose line, D90% values show that 90% of the MR-defined lesions were still covered by nearly 120% of the prescription dose
- Case B is an example where the MR-defined DIL is cooler due to its closer proximity to the urethra than expected based on the mental fusion contour

Conclusion

- If the goal of treatment is to ensure 100% coverage of the DIL, mental fusion is a compelling alternative to a deformable registration approach
  - Potential to reduce operating room times
  - Especially relevant in resource-constrained settings where on-site MRI may not be available, as mental fusion could be based on older image data or biopsy reports
- If the goal of treatment is dose escalation or focal therapy, a deformable registration method is critical
  - Both Dice coefficient data and qualitative inspection shows that mental fusion could lead to a geographic miss
  - Eliminates operator skill & experience dependance

While the simplicity of a mental fusion approach is compelling, DIL dose escalation & focal treatments should utilize deformable registration

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More Info

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