Purpose:

To develop a robotic system to implant high dose rate brachytherapy (HDR-BT) needle configurations meeting clinical dose objectives while avoiding puncture of non-target structures. This system consists of (1) a robotic needle insertion device, (2) needle and dose planning software, and (3) a human with no clinical experience.

Methods:

Acubot-RND is a joy-stick controlled 7-DoF stereotactic needle insertion robot with a remote center of motion (RCM) allowing needle pivot around the RCM point. For this project, a digital needle coordinate input and execution system was developed to replace the analog joy-stick control. Custom pelvic phantoms were built, CT imaged, and contoured. A custom needle-geometry optimization engine was used to generate a planned needle configuration (PNC) within the robot workspace and tailored to the phantom anatomy. Configurations of parallel and angulated needles (up to 53 deg. from parallel) were instructed to avoid puncture of the critical structures near the penile bulb (CSNB). The PNC was transferred to Acubot for sequential insertion. After each insertion, the robot released the needle in place. Needle stylets were passed through the needle and deposited in the phantom during needle retraction by the human user making the implanted needle configuration (INC).

Results:

Two phantoms were implanted using the robotic system. Post-implant CT were obtained, puncture avoidance of the CSNB, pubic arch, and urethra confirmed, and the INC digitized for treatment plan generation. Satisfaction of RTOG-0321 clinical dose objectives was verified and quantitatively compared against a phantom implant performed by an experienced physician.

Conclusions:

A clinically-relevant robotic brachytherapy workflow able to avoid the CSNB and guide needles behind the pubic arch while meeting clinical dose requirements was demonstrated. Operation of this system mitigates some reliance on brachytherapy implant expertise. This workflow is valid for both PPI and HDR-BT.
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