MRI-Guided Robotic Prostate Biopsy and Brachytherapy: Update from the EU-funded CoBra Project

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Purpose / Objective

The Interreg 2 Seas (EU)-funded CoBra research initiative is a five year project to develop a novel device for MR-guided robotic biopsy and brachytherapy for prostate cancer. We report on research achievements approaching three years into the work. We present details from several of the work packages: 1) MRI-safe I-125 seed delivery module, and evaluation of MR seed artefact of the MR-guided robot; 2) MRI-safe biopsy system; 3) novel steerable needles developed to improve access to all parts of the prostate; 4) prototype trajectory planning for ideal needle paths from an optimal number of insertion points; and 5) phantoms designed to test MR image quality in the presence of needles and seeds.

Materials / Method

Project milestones and progress are reviewed bi-weekly via web conference and every six months at a steering meeting, led by the University of Lille.

Results

CoBra Robot

- The CoBra–robot is actuated with MR compatible motors. It's placed at the entrance to the bore, targeting the prostate at isocentre. The seed delivery module, placed next to the robot, uses I-125 BEBIG seeds.

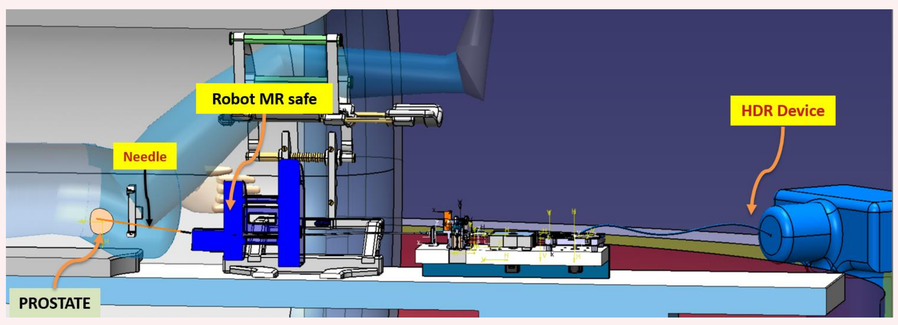

Figure 1. CoBra concept with MRI

- MRI seed distortion tests showed no change in artifact size with (1) no motors active (2) a single motor active (3) both motors active.
- Seeds showed ~11 mm length in imaging (actual length 4.5 mm) & ~4mm diameter (actual diameter 0.8 mm)

Quality Assurance Phantom

- Phantom will be used to confirm geometric accuracy to which needle tips and seeds can be located in MR images.
- Relaxation time has been measured for a potential PTMM consisting of Agar, Carrageenan, $GdCl_3$ and water.
- Phantom construction:
  - PMMA 3D grid (3 x 3 x 3, 15 mm cubes) filled with PTMM, with 3D printed needle guide for precise placement of needle tip.
  - 8 x 5 mm deep PTMM discs (60 mm diameter) with preconfigured loose seeds on each layer in clinically relevant arrangements.
  - Grid and seed stack contained in Perspex cylinder filled with oil.

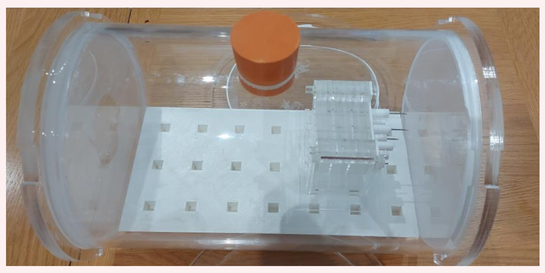

Figure 2. Image of QA phantom with internal grid

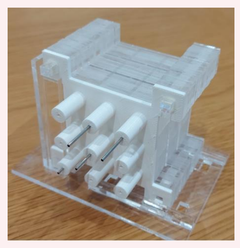

Figure 3. Image of QA internal grid with needle guide.

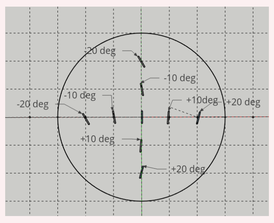

Figure 4. Example of one seed configuration slice to test artifacts with seed orientation.

Trajectory Planning Software

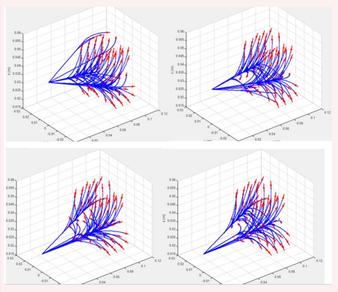

Figure 5. Example image of trajectory outcomes from CoBra software.

The trajectory planning software trials different needle paths based on the input needle parameters. Total tissue damage is taken into account prior to final selection of the trajectory map. Future variations of software could take into account the angle of contact between the needle and the prostate capsule, to improve accuracy

Active Steerable Needle Design

Active steering during the procedure

- Steer around critical organs and anatomical obstructions.
- Correct for positioning errors caused by deflection.
  - Needle curvature follows orientation of the tip
  - Steerable inner needle
  - Flexible outer catheter
  - Large range lateral needle steering
  - Suitable for both stranded and loose seeds

MRI Safe Robotic Biopsy Module

A novel design has been developed for the robotic biopsy module which attaches to the robot. This includes unique methodology to automatically remove prostate core from the needle.

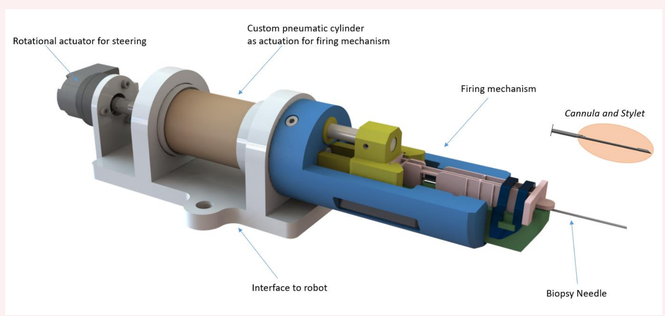

Figure 6. Testing steerable needle design

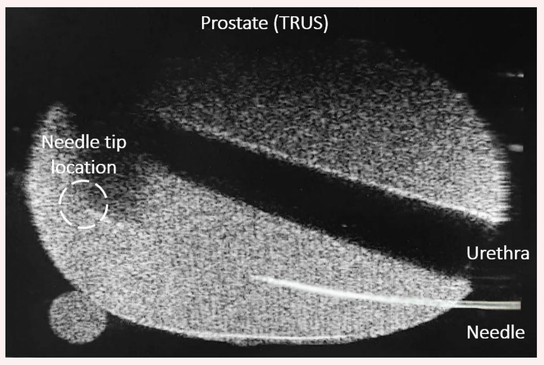

Figure 7. Trajectory of the steerable needle in a prostate phantom visualized with transrectal ultrasound (TRUS)

Conclusions

Approaching the three year point of the project, we present key outcomes and deliverables, on the MRI-guided robotic brachytherapy and biopsy system, prototype parts and software that have been developed and initial test results. The CoBra project is generating new knowledge of benefit to brachytherapy and biopsy, with broader applications in the medical field.