Using Combined X-Ray and MR Imaging for Prostate I-125 Post Implant Dosimetry: Phantom Validation and Preliminary Patient Work

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Introduction

Over the last 15 years permanent prostate brachytherapy has become an established treatment for localised prostate cancer as an alternative to radical surgery or external beam radiotherapy. It is estimated that 30% of patients with localised prostate cancer in the US will undergo brachytherapy implantation involving transperineal insertion of radioactive sources into the prostate under transrectal ultrasound guidance The positioning and distribution of the seeds are crucial to the overall efficacy of the treatment: too "cold" an implant may not treat the disease effectively, and too "hot" an implant may cause unnecessary co-morbidity. Recent advances in computer technology have permitted the development of a real time intraoperative dynamic dose feedback technique based on ultrasound images. The American Brachytherapy Society recommends the evaluation of implant quality by dosimetric analysis based on post-operative Computed Tomography (CT) scan: this not only provides technical feedback to the operator but also guides additional treatments as necessary. The accuracy of 'post-implant dosimetry' is dependent on the accuracy of seed identification and prostate volume delineation within the patient. Current techniques based on CT imaging have inherent difficulties due to lack of soft tissue definition and ambiguous identification of closely grouped seeds. With an aim to improving post implant dosimetry, we are developing a technique which combines x-ray and MR information.

Methods

XMR System The XMR interventional suite comprises a 1.5T Philips Intera scanner and a Philips BV Pulsera mobile cardiac x-ray set. Patients can be moved in less than 60 s between the two systems using a specially modified sliding table [1].

Phantom Work The seed phantom (10 cm cube acrylic box) was made by embedding dummy brachytherapy seeds between two layers of gelatine. Clinical protocols used for prostate imaging were tested for image artefacts (multislice, T_1 and T_2 weighted TSE).

Temperature Measurements were performed using a Luxtron fluoroptic thermometer (Model 790) and two temperature probes, one place against a seed and a reference placed in the gelatine between the seed and the edge of the box. Two clinical scans (survey scan: TFE 20s scan duration, multi-slice TSE scan duration 6min20s) and a scan with maximum SAR level deposition (SAR=3.9 W/kg, modified from ASTM F2182-02 norm) were tested. The phantom was also imaged with an optimised sequence (TSE, 50 slices, turbo factor 5, 0.8×0.8×1.5mm resolution) and x-ray imaged and the two set of images registered.

X-ray MR Registration MR and x-ray image registration is achieved through a combination of calibration and realtime tracking. The x-ray c-arm and table are tracked by a Northern digital Optotrak 3020 using infrared emitting diodes. Calibration of the system is carried out by imaging a specially designed phantom with interchangeable fiducial markers that can be visualised with both MR and X-ray imaging and located using an Optotrak pointer. Full details of the calibration and registration process can be found in ref [2].

Patient Work A 67 year old patient who had previously been implanted with stranded Iodine-125 seeds presented with biochemical failure. There was a clinical requirement to re-stage the disease using MR imaging and to identify seed position in relation to the prostate with an aim to guiding salvage treatment. T_1 and T_2 weighted turbo spin echo images were acquired. The total dose-area-product during the x-ray screening (total time 1.05 min) was 1.81 Gy.cm^2. MR and X-ray images were combined as described above.

Results

Phantom Work: Clinical TSE scans suffered from some slight susceptibility artefact, which could be improved by reducing the turbo factor. No temperature rise was observed for any of the sequences. MR and x-ray images were successfully registered.

Patient Work: Classic prostate protocols gave satisfactory diagnostic and anatomical image quality. The signal voids produced by the seeds could be distinguished individually.

Using the x-ray to MR fusion algorithm it was possible to register the seeds imaged by x-ray onto the MR volume (crosses on **Fig 1)**. All the marked positions correlated with the signal voids of the seeds on the MR images.

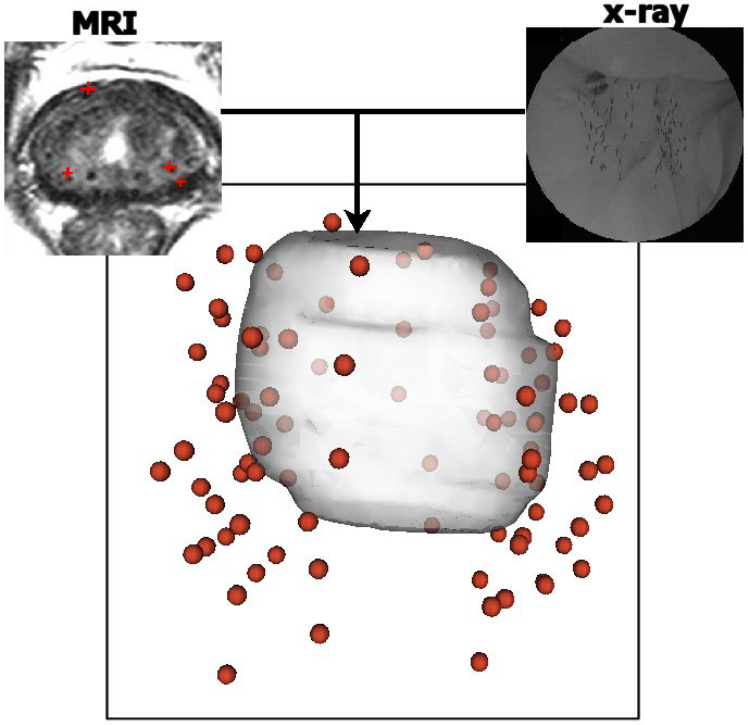

Fig 1 Top: slice through the MR data set and x-ray projection. Bottom: 3D rendering of the prostate and from the registration it is clear that some seeds have been implanted outside the prostate, the one closer to the prostate might have migrated.

Conclusion

By combining the soft tissue definition of MR imaging and the seed localisation accuracy of stereo radiograph imaging we have successfully localised both the prostate and the individual implanted seeds in a phantom and one patient. This technique offers the potential for quick and accurate prostate brachytherapy post-implant dosimetry, potentially improving on CT methods where it is difficult to identify the prostate and differentiate between individual seeds. Better anatomical information about the prostate from MR offers the possibility of improved dosimetry and radiobiology.

References

[1] Razavi et al. (2003) *The Lancet* **362**:1877-1882.

[2] Rhode KS *et al.* (2003) *IEEE Trans Med Imaging* **22**(11): 1369-78.