BrachyView: Tomographic Reconstruction Using TimePix in Post-Implant Dosimetry Checks for Prostate Brachytherapy

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Introduction – Prostate Cancer

- Treatment options
  - Radical prostatectomy
  - Radiation therapy
- LDR: I–125 sources
- Key steps:
  1. Pre–planning (ultrasound volumetric imaging)
  2. Implantation (ultrasound–guided)
  3. Post–implant dosimetry and QA (CT)
- Paradigm shift towards intraoperative dynamic dose planning (IDDP)

Zelefksy et al, ‘Real–time Intraoperative Computed Tomography Assessment of Quality of Permanent Interstitial Seed Implantation for Prostate Cancer’, 2010
Aim to address the gap in IDDP

Novel in-body imaging device being developed

Utilise high-resolution pixelated semiconductor device: Medipix

Later generation known as TimePix (Jakupek, J., "Semiconductor Pixel detectors and their applications in life sciences", 2009)

Multi-modality imaging performed with a single ultra-functional device:


3. CT post-implant dosimetry

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Methodology

- Perform tomographic reconstruction on dummy I–125 seeds implanted into PMMA phantom designed to mimic brachytherapy implant template
- External X-ray source to obtain projection images
- Particular emphasis on partial FOV problem and later, on partial angle problem
- Use iterative approach:
  - Ordered Subset Expectation Maximisation (OSEM)
  - Known to be able to handle noisy and incomplete data well
Methodology
Methodology

- Phantom measurements: single dummy seed, then extended to multiple seed imaging
- Test within FOV and gradually shift outside
- Ideal tomographic reconstructions require complete 180° dataset of projections
Results

- Single seed: on central axis and off-axis measurements
- Can also be artificially combined

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Results

- Shift single seed outside FOV to evaluate capability of tomographic reconstruction
Results – Multiple Seeds

- Insert 8 seeds into phantom so as to cover ‘all possible cases’
  1. Inner cases near urethra
  2. Outer cases near prostate boundary
Since these phantom measurements were not designed to keep seeds constrained within FOV of the single detector, partial sinograms move in and out rapidly.
Results – Multiple Seeds

- Quantitatively evaluate by comparing with expected values in phantom positions A1, A5, B2, B4, D2, D4, E1, E5

Reconstructed Seed Positions – Tomography

Slice

- OSEM Reconstructed Positions
- Expected Positions
Results – Partial angle reconstructions

- Evaluate the capability of the OSEM algorithm to reconstruct for sinograms of degrading quality

Angle iteration=2
Results – Partial angle reconstructions

- Evaluate the capability of the OSEM algorithm to reconstruct for sinograms of degrading quality

Angle iteration = 4
Results – Partial angle reconstructions

- Evaluate the capability of the OSEM algorithm to reconstruct for sinograms of degrading quality

Angle iteration = 6
Results – Partial angle reconstructions

- Evaluate the capability of the OSEM algorithm to reconstruct for sinograms of degrading quality

Angle iteration = 10
Future Work

- Further investigation into possible correction/calibration factor for offset distortion
- Simulation work in GATE (GEANT4) to confirm this correction factor
- Ongoing work in refining/redesigning reconstruction algorithms for best results. Masters students carry on CT project
Discussion & Conclusion

- The BrachyView system is a transrectal, ultra-functional imaging probe for PPB.
- Capable of performing:
  - Pre-planning
  - Intra-operative treatment planning (or IDDP)
  - Post-implant dosimetry measurements
- This proof of concept study indicates that BrachyView is capable of resolving seeds accurately for post-implant CT dosimetric studies.
- Further work is required to refine this approach, but the feasibility concept has been shown using TimePix as an in-body imaging plane for CT measurements of the prostate and LDR PPB implants.
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