Improving Precision in Percutaneous Needle Placement

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Abstract

Introduction: Small tumours must frequently located with percutaneous needles for biopsy or therapy. If the placement of the needle to improve a false negative may result on biopsy or the lesion may not be cured by therapy. At minimum, the needle must be reproducible. To improve percutaneous needle interventions, we have implemented a method for characterizing error and providing post-procedure feedback to a clinician.

Methods: The method was tested in the context of prostate brachytherapy, as it poses particular challenges: the placement of the radioactive sources is critical for success, and the accuracy of the procedure is dependent on the precision of the needle placement.

Results: When tested on the nine clinical datasets, the algorithm reconstructed 100% of implanted needles within seconds on commonly available computers. When the implanted needles were reconstructed as sine waves, 70% of needles had wavelengths less than 2mm, and 50% of the implanted needles had wavelengths less than 2mm.

Conclusions: In the context of prostate brachytherapy, a method for identifying needle trajectories could be used to guide needle placement to correct for the error observed. By using this algorithm to note these parameters and then correct for them, the precision of percutaneous needle interventions may be improved, resulting in improved outcomes in biopsy and therapy.

Objectives

- Needles used for percutaneous biopsy or therapy may not hit their target for a variety of reasons: patient motion, needle deformation and tissue edema among them.
- This is especially important in prostate brachytherapy, where the position of the needles determines the position of the radioactive sources and hence the effectiveness and resulting complications of the procedure.
- We propose four parameters to help measure needle and needle tract deviation in prostate brachytherapy: wavelength, amplitude, angle and displacement.

Our goal with these parameters is twofold:

1. Provide feedback to clinicians that could be used to adjust interventions on subsequent patients.
2. Characterize deformation of needle tracts so that large-scale patterns of displacement can be found and corrected.

- We hope that this characterization and feedback will lead to more precise needle placement in prostate brachytherapy.

Methods

Initial Reconstruction

- Brachytherapy seeds were imaged with fluoroscopy and reconstructed in three dimensions.
- Needle tracts were isolated in the three-dimensional seed cloud using a highly accurate seed-matching method from Gordon et al.,
- We then (1) compared each needle tract to the planned needle tract and (2) found the sine wave of best fit for each needle tract.

Wavelength

The wavelength of each needle tract, as reconstructed by sine wave. Wavelength is the length of one complete sinusoidal cycle: from peak to peak, for example.

Amplitude

The amplitude of each needle tract, as reconstructed by sine wave. Amplitude is the maximum deviation of the sine wave from the line-of-best-fit of the needle.

Displacement

The red points show the planned centroid of each needle, and the black points show the true centroid of each needle. Displacement is represented by the line connecting each pair.

Angle

The blue points show the planned insertion points of the needles, and the lines represent the direction of the needle, angling away from the insertion point.

Results

Data for nine patients were analyzed, for a total of 224 needle tracts.

Displacement: Mean radial displacement was measured at 1.0mm ± 2.3mm.

Angle: Mean angle from the needle axis was 8.0° ± 5.2°.

Wavelength: 70% of needle tracts had a wavelength < 20mm.

Amplitude: 93% of needle tracts had an amplitude < 2mm.

Including needle isolation, the algorithm terminated in <7s on a standard laptop computer.

Conclusions

Because of the short runtime, this algorithm could reasonably be used in a clinical setting, to provide feedback to clinicians. For this clinician, there seems to be minimal radial displacement of the needle tracts. However, the angle of the needle tracts appears to clinically significant: Needle wavelength could be concerning since there are multiple bends over the course of the tract. Nonetheless, the amplitude of each tract is small enough to make the short wavelengths less concerning.

Factors that appear to be affecting the position of the needle tracts, in this case angle, could be corrected by correlating the parameter with anatomy and adjusting the needle trajectory or stiffness accordingly.

References