

Ultrasonic detection and imaging of two common types of prostate-brachytherapy seeds using singular spectrum analysis

Jonathan Mamou and Ernest J. Feleppa
Lizzi Center for Biomedical Engineering
Riverside Research Institute
New York, NY

Brachytherapy to treat prostate cancer uses transrectal ultrasound to guide transperitoneal needle implantation of titanium-shelled radioactive seeds. The standard external dimensions of all seeds used for prostate brachytherapy is 4.5 mm in length and 0.85 mm in diameter. Gland deformation and needle deflection during implantation allow seed-placement errors that cause suboptimal dosimetry. Conventional ultrasound cannot reliably image implanted seeds because of shadowing, clutter, and seed specularities; therefore dosimetry errors caused by seed misplacements cannot be corrected in the operating room and currently require extensive post-implantation external-beam radiation to compensate for inadequate brachytherapy dosage.

An algorithm based on a signal-processing framework called singular spectrum analysis (SSA) has shown encouraging potential for effectively imaging two commonly used types of prostate-brachytherapy seeds: those containing radioactive palladium (Pd-103) and those containing radioactive iodine (I-125). The seed-imaging performance of the SSA algorithm was compared quantitatively to the performance of conventional B-mode ultrasound images.

The SSA algorithm was tested in two types of laboratory experiments conducted with a single seed. The first experiment evaluated the performance of the SSA algorithm imaging a single seed inserted in an acoustically transparent gel pad. The second experiment evaluated the algorithm imaging a single seed inserted in a degassed piece of *ex vivo* beef tissue. Both experiments were conducted with both types of seeds. Performance was evaluated as seed orientation with respect to the transducer was varied. Ultrasound scanning was performed in transverse and longitudinal planes with angles between the beam axis and the normal to the seed axis varying from 0 to 22 degrees. (Longitudinal-scan data were acquired by scanning in a plane parallel to the long axis of the seed and transverse-scan data were acquired by scanning in a plane perpendicular to the plane in which the seed was tilted.)

The algorithm extracts pairs of eigenvalues from the autocorrelation matrix of seed echo signals. Selected eigenvalues are used to compute a “P-value” for seed presence. The algorithm was applied to echo signals obtained using a 5-MHz transducer. Performance was denoted by a score computed from P-values. P-values were then color-coded and superimposed on conventional B-mode images to yield a “P-mode” image.

The gel-pad and *ex vivo* beef experiments indicated that the SSA algorithm was able to image I-125 and Pd-103 seeds more successfully than conventional B-mode methods could. Figure 1 shows typical P-mode images obtained from longitudinal scans of both types of seeds in *ex vivo* beef tissue at different angles. Scores for both seed types

in beef varied from 70 to 40 dB over the range of angles studied. Scores computed from B-mode images were approximately 30 dB lower indicating superior contrast for the SSA algorithm, which successfully detected both types of seeds over a range of angles likely to be encountered in the operating room.

An encouraging conclusion of this study is that we were able to image these two different types of brachytherapy seed with a single algorithm. This suggests that the algorithm may be robust with respect to the type of seeds that is used, and this robustness could be very valuable clinically where many types of seeds can be encountered even though the overall geometry (i.e., the diameter and length) of all seeds is standardized.

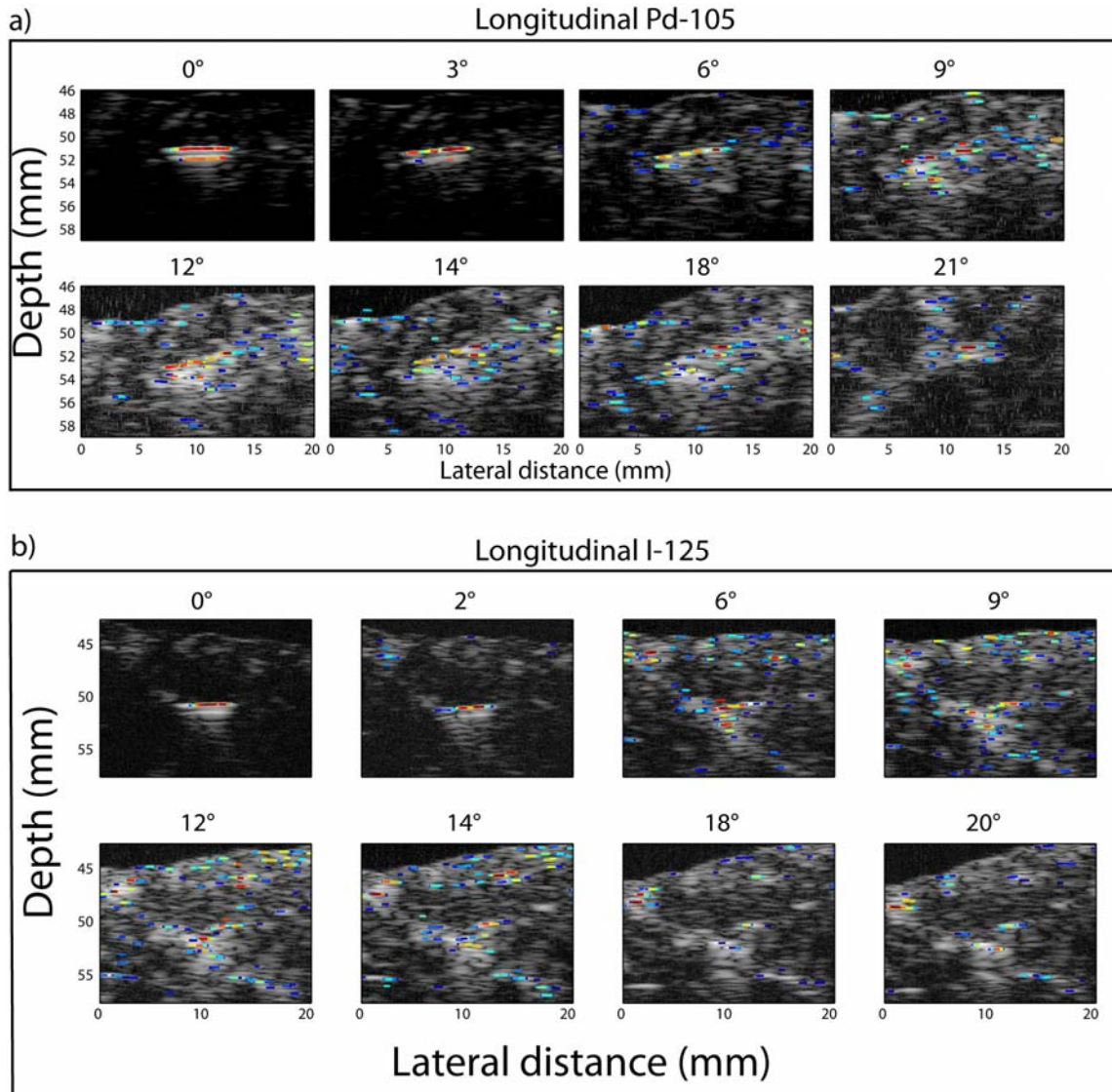


Fig. 1 P-mode images of a Pd-103 (a) and I-125 (b) seeds inserted into a piece of *ex vivo* beef. The P-values have a dynamic range of 40 dB.

This research is supported in part by NIH grant CA098465.