QUANTIFICATION OF SEQUENCE PARAMETER EFFECT ON GEOMETRIC DISTORTIONS CAUSED BY A TITANIUM BRACHYTHERAPY APPLICATOR

Steven M Shea[1], Abbie Diak[2], Murat Surucu[2], Matthew Harkenrider[2], and Joseph M Yacoub[1]

[1]*Radiology, Loyola University Chicago, Maywood, IL, United States,* [2]*Radiation Oncology, Loyola University Chicago, Maywood, IL, United States*

Target Audience: MRI physicists, Radiation Oncology Physicists, Radiation Oncologists, Pelvic Radiologists

Introduction: Brachytherapy (BT) is a key component in the treatment of cervical cancer [1]. Historically, cervical BT has been planned with orthogonal x-rays with dose prescribed to a point, but 3D planning and image guidance is gaining in popularity [2]. MRI is an ideal choice for lesion visualization but most commercially available BT applicators are either MR unsafe or MR conditional, which can distort the applicator geometry. MR imaging artifacts near the tandem tip are often observed, which can cause systematic errors in applicator reconstruction and have dosimetric consequences [3]. Prior phantom studies have looked into quantifying artifacts caused by titanium applicators but have typically focused on a single sequence variant [4,5]. We proposed to investigate specific changes to bandwidth and voxel size to quantify the effect on applicator artifact at 1.5T.

Methods: An acrylic phantom (Figure 1a) was constructed to rigidly hold a MR conditional, titanium Fletcher-Suit-Delclos-style applicator set (Varian Medical Systems) for imaging on CT (Philips Brilliance) and 1.5T MRI (Siemens Magnetom Aera). The phantom was filled with 0.1 mM of Gadobutrol in distilled water to generate a T1 of approximately 1.2 s. Several variants of MRI parameters were tried for 2D T2-weighted turbo spin echo imaging in comparison against the standard clinical protocol with the criteria to keep relative SNR loss less than 20% and imaging time as short as possible. Two 3D sequences were also used for comparison with similar parameters (Table 1). The applicator tandem was segmented on axial CT images (0.4x0.4x1.5mm^3 resolution) and the CT images were registered to the 3D MR images in Eclipse (Varian). The applicator volume was then overlaid on all MRI sets in 3D-Slicer [6] (Figure 1b & 1c) and distances were measured from the tandem tip to the MRI artifact edge [5] in right/left/superior and anterior/posterior/superior directions from coronal and sagittal 2D acquisitions, respectively, or 3D data reformats. Artifact regions were also manually contoured in coronal/sagittal orientations for area measurements (Figure 2).

Name	TR (ms)	TE (ms)	ETL	Slices	Matrix	FOV (mm)	TA (s)	Avgs	Res (mm^3)	BW (Hz/px)	Rel SNR
2D T2 std	*3580*	*91*	*15*	*24*	*256*320*	*250*250*	*121*	*1*	*0.98x0.78x4*	*200*	*1.00*
2D T2-A	4471	91	25	24	256*256	250*250	89	1	0.98x0.98x4	500	0.79
2D T2-B	5552	91	25	32	192*192	250*250	172	2	1.30x1.30x3	815	1.01
2D T2-C	5980	92	25	32	256*256	250*250	370	3	0.98x0.98x3	815	0.81
2D T2-D*	5961	91	25	32	256*256	250*250	369	3	0.98x0.98x3	650	0.91
3D T2-TSE	1700	96	80	120	256*256	250*250	377	2	0.98x0.98x1	630	NA
3D T1-GRE*	3.33	1.09	NA	128	195*256	240*240	415	2	1.23x0.94x1	610	NA

Table 1: MRI sequence parameters for 2D T2-weighted TSE, 3D T2-weighted TSE (i.e. SPACE, VISTA, or CUBE), and 3D T1-weighted GRE. 2D T2-std was the standard clinical protocol at our institution and was changed by varying resolution and bandwidth. "*" protocols were taken from Kim et al. [5] for comparison.

Results and Discussion: Figure 3 shows the maximum and averaged values for distance and area measurements. As expected, reductions in voxel size and readout bandwidth reduced artifact size. Interestingly, bandwidth increases yielded reductions in area and distance measurements even with a voxel increase (T2-STD vs T2-A). This could prove useful for protocol optimization where more aggressive techniques (T2-C and T2-D) are not feasible due to increased imaging times of over six minutes. 3D T2-weighted techniques (SPACE/VISTA/CUBE) would be optimal at 1.5T for lesion visualization, registration with CT, and high-through plane resolution, but tip localization was the poorest of all techniques examined. Results were different than those obtained in Kim et al. (T2-D: 3.1 vs 7.5 mm; 3D T1-GRE: 3.8 vs 2.5 mm). This is likely due to differences in field strength, applicator set, and applicator orientation.

Conclusion: We have characterized BT applicator induced geometric distortions across multiple sequence parameters at 1.5T. Future work will focus on confirming these results in patients and finalizing an optimal protocol that balances artifact reduction with imaging time and lesion visualization.

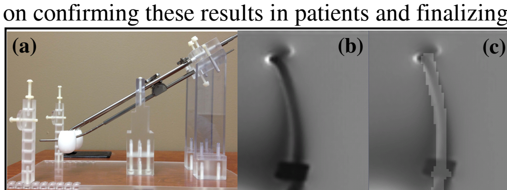

Figure 2: (a) phantom holder with applicator; (b) T2-STD sag; (c) T2-STD sag with tandem overlay.

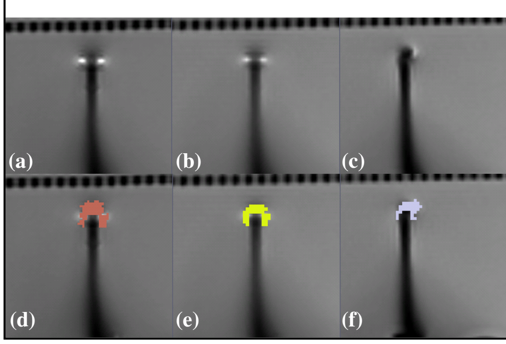

Figure 2: Coronal images of (a) T2 std; (b) T2-A; (c) T2-C; and (d-f) those same images overlaid with segmented artifact regions at the tip.

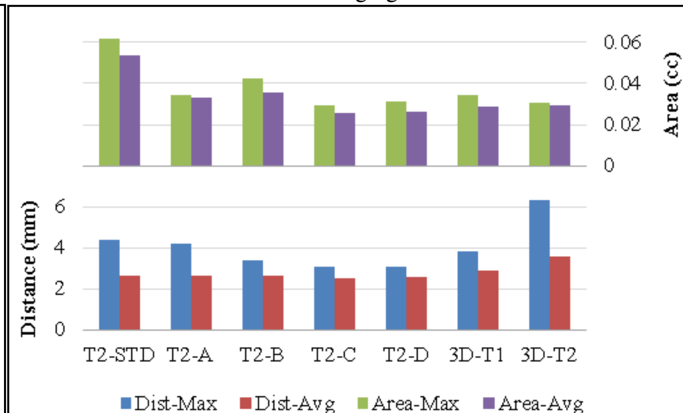

Figure 3: Maximum and averaged values for distance and area measurements of artifact extent from applicator tip. Smaller values indicate more agreement with CT results.

References: [1] Morris M et al. N Engl J Med. 1999; 340: 1137-43 [2] Viswanathan AN et al. Brachytherapy. 2012; 11:33-46. [3] Tanderup K et al. Radiother Oncol. 2008; 89(2): 156-63. [4] Haack S et al. Radiotherapy & Oncology. 2009; 91:187-93. [5] Kim Y et al. Int J Radiation Oncology Biol Phys. 2011; 80:947-55. [6] Fedorov A et al. Magn Reson Imaging. 2012; 30:1323-41.