Displacement of neurovascular bundles before and after MRI-guided prostate brachytherapy

P. Y. Wong[1,2], A. Szot[1], S. Haker[1], K. H. Zou[1], A. V. D'Amico[3], C. M. Tempany[1], and N. Hata[1]

[1]Surgical Planning Laboratory, Department of Radiology, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, United States, [2]Faculty of Medicine, University of Toronto, Toronto, ON, Canada, [3]Department of Radiation Oncology, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, United States

INTRODUCTION

MRI-guided prostate brachytherapy is feasibile and is efficacious for early-stage prostate cancer. The current standard of practice is to attempt to reduce radiation doses to the bilateral neurovascular bundles (NVBs) adjacent to the prostate gland in order to prevent possible erectile dysfunction (1-4). It has been demonstrated MRI can visualize the NVBs, and hence should be useful for intra-procedural dosimetry planning during MRI-guided brachytherapy (5,6). The purpose of this study is to further measure the variation in position of the NVBs. If significant mobility exist, it may need to be taken into account in dosimetry planning. Specifically in this study, we assessed the displacement of the NVBs in pre- and post-operative MR imaging of subjects undergoing MRI-guided brachytherapy and report the nature of NVB movement.

METHODS

A retrospective anaalysis of 30 patients was performed. All men had localized prostate cancer diagnosed between November 1997 and January 2000 and treated with MR-guided brachytherapy. For each patient, a pre-brachytherapy MR imaging at 1.5T (including a T1-weighted axial fast-spin echo) was performed with endorectal coil 1-3 weeks before brachytherapy. Six weeks after the brachytherapy, a second MR exam (including axial T2-weighted fast-spin echo images) was obtained without endorectal coil. Both volumes were acquired with the patient in supine position.

Total prostate glands (TGs) and NVBs were manually segmented using the 3D Slicer, a surgical simulation and navigation software tool. The anatomical centers (centroids) of the TGs as well as the right and left NVBs were determined on each axial T1W and T2W slice. The NVB centers were then registered using rigid transformation, previously demonstrated (5), which minimized the mean squared error between the distances between the pre- and post-brachytherapy NVB centers. The same image processing method was applied separately to the centers of the TGs.

After registration, we performed three sets of measurements to compare the changes in location of NVBs before and after brachytherapy. First, we measured the medial-lateral and anterior-posterior distance between the right and left NVB centers. Second, we assessed medial-lateral narrowing of the NVB centroids at the apex and base. Third, the change in distance between the TG center to the right and left NVB centers was measured. Comparisons were performed using paired Student's t-tests, with the null hypothesis in each case indicating that the population means of the underlying paired measurements were equivalent. The association between NVB center displacement and change in prostate volume was also assessed.

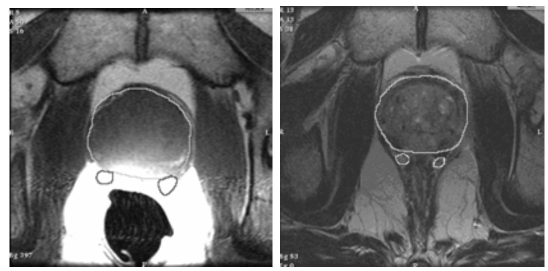

Fig. 1. Representative segmentation of NVBs from MR images obtained 20 mm from the prostatic base. (left) Pre-brachytherapy image. (right) Post-brachytherapy image.

RESULTS

The median patient age was 65 (range: 50 to 80) years, and the mean prostate volume was 50 mL before and 46 mL after brachytherapy. The medial-lateral distance between the right and left NVB centers was reduced after brachytherapy (36.1 mm vs 27.2 mm, $p<0.001$), while there was no change in the anterior-posterior direction ($p=0.10$). The medial-lateral narrowing of the NVB centroids at the prostatic base was greater than at the apex (2.2 mm vs. 3.9 mm, $p=0.038$). The measurement results of anatomical locations are illustrated in (Fig. 2). As can be seen the NVBs migrate centrally. There was no association between NVB displacement in the medial-lateral direction with change in prostatic volume (Fig. 3) or the prostatic medial-lateral dimension. There was minimal change in the center of the prostate gland ($p=0.39$ in ML direction, 0.56 in AP direction).

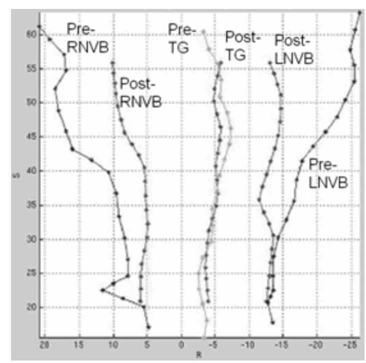

Fig. 2. Location of the centers of the total prostate gland (TG), and right and left neurovascular bundles (RNVB and LNVB) before (Pre) and after (Post) brachytherapy. Anterior view.

DISCUSSION

The characterization of displacement from our study suggests that there are indeed changes in location and movement of NVBs in relation to the prostate gland after brachytherapy. This infers that it is probable that some motion is likely during the brachytherapy. However, it should be noted that this was not performed in real time during treatment. But the results do demonstrate that the central shift, greater at the apex than base should be considered in treatment. This movement may particularly be useful during inverse treatment planning by predicting radiation doses to NVBs given potential shifts in location.

In summary, we analyzed the displacement of the bilateral NVBs from before to after brachytherapy. These experiments demonstrated that there is significant central migration of the bilateral NVBs in the medial-lateral direction of 9.1±3.6mm after brachytherapy, and NVBs moved centrally to a greater extent at the prostatic base than at the apex. This displacement is independent of changes in prostate volume after brachytherapy.

Table 1: Mean and standard deviation of anterior-posterior and medial-lateral change of prostate gland and NVBs

Measurement	mean ± SD (mm)
(a) Distance between right and left NVBs	
- ML displacement (*)	9.1±3.6 medially
- AP displacement	0.1±0.6 anteriorly
(b) Total prostate gland	
- ML displacement	0.0±0.0
- AP displacement	0.0±0.0
(c) Right and left NVB centers to TG centers	
- ML displacement (*)	4.4±1.7 medially
- AP displacement	0.1±0.3 anteriorly

(*) indicates statistically significant displacement.

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