The visualization of periprostatic nerve fibers using Diffusion Tensor Magnetic Resonance Imaging with tractography

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Aims and objectives

The decision whether to preserve or resect neurovascular bundles (NVBs) or the type of nerve-sparing procedure (intrafascial and interfascial) to be performed during radical prostatectomy (RP) are some of the most common and difficult points that urologists must consider.

For that judgment, the information concerning mostly the presence and location of extracapsular extension (ECE) and the visualization of periprostatic nerve fibers are important.

MRI has revealed a good diagnostic performance of diagnosing ECE, however the visualization of periprostatic nerve fibers itself is difficult and has not been solved.

Periprostatic nerve trunks and vessels has been believed to exist locally near the postero-lateral region with a definite bundle formation of so-called "NBVs" covered by lateral pelvic fascia after Walsh first commented in 1983 [1].

However in the current study performing pathologic analysis of non-nerve-sparing RP specimens, several authors suggested anatomic variations exist regarding the course of NBVs and nerve fibers often spread sparsely from the lateral aspect of prostate to the anterior without definite bundle formation [2-4].

Diffusion-tensor imaging (DTI) and tractography have emerged as noninvasive MRI techniques providing in vivo information on white matter structure. The method is based on the sensitivity of water protons measured in the microstructural environment.

This technology has been used for neurosurgical planning to aid in the removal of brain tumors as well as for neural pathway mapping of the brain, spinal cord, and brachial plexus.

This technology has recently been used also to map periprostatic nerve fibers [5-7].

The purpose of this study is to evaluate if DTI technique with tractography can visualize periprostatic nerve fibers comparing the change of DTI before radical prostatectomy between nerve-sparing and non-nerve-sparing hemisphere.

Methods and materials
Fifty-two patients (mean age; 67.7 years, pT1 in 3, pT2 in 35, pT3 in 14) with prostate cancer underwent 3-Tesla MRI including DTI before and after radical prostatectomy between January 2010 and July 2012.

The mean interval between pre-DTI and RP, and RP and post-DTI was 35 days (range: 2~124 days) and 324 days (range: 38~460 days), respectively.

This retrospective study was approved by the institutional review board in our institute, and the written informed consent was obtained for MRI exam before RP and was waived for MRI exam after RP.

Data postprocessing and Image analysis

DTI tractography image processing was performed using MedINRIA 1.9, Tutorial version 2.0 (Sophia-Antipolis, Research Project Asclepios, Codex France).

The periprostatic nerves were analyzed tracking separately the fibers to the left and right hemisphere of the prostate at the base, midgland, and apex for each patient using 3D T2-weighted images as localizer.

After plotting a ROI over the posterolateral region in tangential contact with the prostatic capsule, the fiber tract number was evaluated in a quantitative approach at the left and right hemisphere and at each level of the prostate gland. Almost same fiber tracking analysis was performed after RP, considering the same plane and the same orientation to obtain a standard images for the best NBV evaluation.

Statistical Analysis

Tract number at base, midgland, apex level was compared using Cochran’s Q test and McNemar test with Bonferroni adjustment. Comparison of nerve number before and after RP was performed in nerve-sparing and non-nerve-sparing groups using paired t test. A p-value less than 0.05 was considered to indicate a statistically significant difference. Statistical analysis was performed with SAS software version 9.3 (SAS Institute, Cary, NC).

Results

Five of 52 patients (9.6%) were excluded from the analysis due to poor image quality (2 patients for pre-RR DTI's poor image and 3 patients for post-RP DTI's poor image).

Among remaining 94 hemispheres (47 patients), eight hemispheres in which partial nerve-sparing surgery was undertaken, were excluded.
The final hemisphere’s number in our series was 86.

**Difference among in the base, midgland, and apex level before RP**

Tract number before RP was highly variable between individual patients. For example, total tract number between patients ranged from 3-1252 (SD 309.5).

When divided into regions, tract number is highest in the base level and lowest in the apex level at both hemispheres. The mean periprostatic tract number was 210.2±159.6 (range, 0~693), 100.8±110.8 (range, 0~463), and 69.7±81.8 (range, 0~321), respectively, at base, midgland, and apex of the right hemisphere (Fig 1). Those corresponding figures of left hemisphere was 168.8±149.8 (range, 0~577), 105.2±116.8 (range, 0~435), and 77.4±93.5 (range, 0~348), respectively (Fig 2). In right hemisphere, there was a significant difference among three levels (p<0.0001, Cochran’s Q test) and McNemar test with Bonferroni adjustment showed significant difference between the base and midgland level (p<0.01) and base and apex level (p<0.01). The difference did not significant level between the midgland and apex level. In similar, in left hemisphere, there was a significant difference among three levels (p=0.0015, Cochran’s Q test) and McNemar test with Bonferroni adjustment showed significant difference between the base and midgland level (p<0.01) and base and apex level (p<0.05). The difference did not significant level between the midgland and apex level.

There was no significant difference at each standardized region (ie, base, midgland, apex) between the right and left hemispheres (p=0.54).

**Change of the pre- and post-RP status between nerve-sparing and non-nerve-sparing group**

In non-nerve-sparing group (n=69), the tract number significantly decreased at base (218.8±198.8 vs. 60.5±88.7, p<0.0001), midgland (124.1±134.5 vs. 32.5±45.7, p<0.0001), and apex (103.1±127.4 vs. 29.1±57.1, p<0.0001) after RP (Fig 2a).

However, in nerve-sparing group (n=17), the tract number did not significantly changed at base (170.5±139.7 vs. 127.7±146.0, p=0.078), midgland (134.3±140.8 vs. 83.7±58.3, p=0.067), and apex (64.1±68.4 vs. 62.3±61.9, p=0.46) after RP (Fig 2b). Representative two cases are shown (Figs 3,4).

**Images for this section:**
The mean periprostatic tract number was 210.2±159.6 (range, 0~693), 100.8±110.8 (range, 0~463), and 69.7±81.8 (range, 0~321), respectively, at base, midgland, and apex of the right hemisphere. Those corresponding figures of left hemisphere was 168.8±149.8 (range, 0~577), 105.2±116.8 (range, 0~435), and 77.4±93.5 (range, 0~348), respectively.
Fig. 2: Change of the pre- and post-RP status between nerve-sparing and non-nerve-sparing group (a) In non-nerve-sparing group (n=63), the tract number significantly decreased at base (218.8±198.8 vs 60.5±88.7, p<0.0001), midgland (124.1±134.5 vs 32.5±45.7, p<0.0001), and apex (103.1±127.4 vs 29.1±57.1, p<0.0001) after RP. (b) However, in nerve-sparing group (n=15), the tract number did not significantly changed at base (170.5±139.7 vs 127.7±146.0, p=0.078), midgland (134.3±140.8 vs 83.7±58.3, p=0.067), and apex (64.1±68.4 vs 62.3±61.9, p=0.46) after RP.
Fig. 3: Fig. 3 (a) Preoperative and (b) postoperative visualization of periprostatic nerve fibers using diffusion tensor MRI with tractography in a 64 year-old-man undertaking both sides non-nerve-sparing prostatectomy. Periprostatic tract number had dramatically decreased at both hemispheres after surgery.

Fig. 4: Fig. 4 (a) Preoperative and (b) postoperative visualization of periprostatic nerve fibers using diffusion tensor MRI with tractography in a 67 year-old-man undertaking prostatectomy with right side non-nerve-sparing and left side nerve-sparing. Periprostatic tract number had dramatically decreased at right hemisphere and mostly remained at left hemisphere after surgery.
Conclusion

DTI technique tractography may be feasible in the visualization of periprostatic nerve fibers. This information could be useful for guiding propernerve-sparing surgery using an intra-fascial or extra-fascial roboticapproach, thereby ensuring recovery of erectile function after RP.

Further study is required to correlate DTI findings to gold standard anatomic specimens.

Personal information

This is the first study to compare the change of pre-and post- surgical DTI tractography between nerve-sparing and non-nerve-sparing hemisphere. Reflecting the result the tract number significantly decreased in non-nerve-sparing group compared with nerve-sparing group and the tract number was highest in the base level and lowest in the apex level could support that DTI tractography may be feasible to visualize periprostatic nerve fibers.

However, in the point of the principle of DTI, we recognize the limitation of DTI that could not recognize individual thin nerve and also depicted non-nerve linear structure, such as fibromuscular tissue, arteries, and veins. The true usefulness of DTI tractography for mapping periprostatic fibers must be judged by the gold standard pathologic correlation for reference.

The limits of tractography may be related to the DTI technique that suffers from artifacts, partial-volume effects, propagation errors and contamination of the tensor by crossing and kissing fibers within a single voxel (Intra Voxel Inchoerent Motion). In our series, in fact, we discarded five patients (9.6%) because of poor imaging quality. This percentage is similar to Panebianco' report (8.3%) [7].

There were certain limitations to the scope of the present study. The major limitation of this study is a lack of gold standard anatomical correlation for reference. Second, the size of patient sample was relatively small. Further prospective and larger studies are needed. Third, the periprostatic nerve located in the anterior aspect of the prostate was not evaluated by DTI tractography in our series.

References


