Potential Utility of High Resolution Diffusion Tensor Imaging in Radiation Therapy of Prostate Cancer

Min-Sig Hwang, Ph. D
Medical Physics Resident
= Nerve
★ = Urethra

Seminal Vesicles

Prostatic urethra

Base

Anterior

Posterior

Apex

Map in upper right hand corner shows approximate location of cross section (Black line)
Prostate Gland & Nerve Distribution

- Most nerves are exterior or toward the extreme periphery of the prostate
- Most nerves are in the posterior-lateral location but tend to coalescence in the anterior prostate as one moves toward the apex
- Nerves coalesce around the base of the seminal vesicles and travel along the outside of the ejaculatory ducts
Why Do We Use High Resolution DTI?

- To understand the underlying sources of MR signals, in order to permit clinical interpretation.
- Tissue relaxation properties (or diffusion properties) provide contrast that may not be visible to the naked eye.
Basic principles of diffusion weighted MR imaging
Basic principles of diffusion weighted MR imaging
Basic principles of diffusion weighted MR imaging

\[ S = S_0 \exp(-bD), \]

\[ b = \gamma^2 G^2 \delta^2 (\Delta - \delta/3), \]

\[ \tau = \Delta - \delta/3 \]
From diffusion coefficient to diffusion tensor

Elements of b matrix of each scan

\[
\begin{pmatrix}
B_{xx} & B_{xy} & B_{xz} \\
B_{yx} & B_{yy} & B_{yz} \\
B_{zx} & B_{zy} & B_{zz}
\end{pmatrix}
\]

Diffusion tensor

\[
\begin{pmatrix}
D_{xx} & D_{xy} & D_{xz} \\
D_{yx} & D_{yy} & D_{yz} \\
D_{zx} & D_{zy} & D_{zz}
\end{pmatrix}
\]

\[
\begin{pmatrix}
\lambda_1 & 0 & 0 \\
0 & \lambda_2 & 0 \\
0 & 0 & \lambda_3
\end{pmatrix}
\]

\[\lambda_1, \lambda_2, \lambda_3, \text{FA, } <D>, \& \]

Fiber tracking

Diffusion ellipsoid

DTI
Magnetic Resonance Imaging at 11.1 T & 17.6 T Magnet

Isolated fixed biological tissues: six cadaver prostates
- incubated in PBS in 2 days
- imaged in hydrogen-free solution

Diffusion MRI (High Angular Resolution Diffusion Imaging)
- b value: 900 s/mm²
- $\Delta / \delta$: 13.4 ms / 1.8 ms
- PGSE in 21 directions of TR/TE: 4500 / 27.1 ms

MR Data processing: fanDTasia

Histology & Image analysis: H&E stained dissection and image Scope
Fiber tracking of Human Prostate

Data collected @ 11T magnet
Example of small sections of an ex vivo cadaver prostate and their nominations.
Direct histological validation of the detection of cavernous nerve fibers at a high spatial resolution
Limitations

- Technical issues for In Vivo application: (e.g., RF coil, Optimized pulse sequence)
- Resolution trade-off
- Artifacts (fiduciary)
Summary

- The HR diffusion tensor imaging may locate tumor in the prostate gland and its surrounding cavernous nerves without tissue destruction.

- Cancer induced changes in prostate gland might be monitored non-invasively using DTI.

- These data demonstrate the feasibility of generating high resolution fiber tract maps of the excised and fixed human prostate.

- The DTI has the potential to assist radiation therapy to prostate cancer by developing anatomic maps of the cavernous nerve fibers, providing a potentially important tool or “road map” for guiding nerve preservation.
Potential

✓ Application of Cutting-edge imaging (MRI) Techniques to Clinical Platforms of Radiation Therapy

- Image Guided Stereotactic Body Radiation Therapy (SBRT)
- MRI guided Treatment Planning (HDR)
- Treatment Verification using Imaging (MRI)
Acknowledgements

Stephen Blackband, Ph. D
John R. Forder, Ph. D
Baba Vemuri, Ph. D
Li-Ming Su, MD
Robert H. Allan, MD

Siyoung Jang, Ph. D
Saiful Huq, Ph. D
Thank you.

Keep young forever!