Background
Diffusion tensor imaging (DTI) is a non-invasive imaging technique that measures the diffusion of water molecules in the brain. It is based on the principle that water molecules diffuse randomly in tissues, but the diffusion is Restricted in tissues with a high degree of organization. DTI uses high angular resolution diffusion imaging to map the direction and magnitude of water diffusion in the brain. This allows for the visualization of white matter tracts, which are bundles of axons that connect different regions of the brain.

Physics of Diffusion Tensor Imaging
By adding two magnetic field gradient pulses to a conventional spin echo pulse sequence, the signal of moving water molecules can be determined, and the signal of stationary or "restricted" water molecules can be isolated. The use of two gradient pulses in different directions allows for the estimation of diffusion in multiple directions, and the diffusion tensor can be calculated from the data.

Off-null effects from different diffusion acquisitions, each with a different orientation of the diffusion sensitive gradient planes, generating unique representations of the apparent diffusion tensor, the preferred direction of diffusion, and the diffusion coefficient at each voxel.

Diffusion anisotropy is due to the presence of a particular orientation of the diffusion tensor, which can be graphically represented as a distribution in one of the possible directions.

Transform
The transformation is a change of frame of reference relative to the MR scanner to the local region of interest. The mathematical equivalence of the transformation is the diagonalization of the diffusion tensor. This operation simplifies the matrix representation of diffusion tensor as shown above. The diagonal elements of the diffusion tensors can be calculated from the eigenvalues of the diffusion tensor.

The transformation is a function of the local region of interest and is based on the diffusion tensor. This transformation simplifies the matrix representation of diffusion tensor as shown above. The diagonal elements of the diffusion tensors can be calculated from the eigenvalues of the diffusion tensor.

Clinical Applications

Stroke

- Diffusion weighted imaging is the main imaging modality for detecting acute stroke.
- DTI can identify important structural abnormalities in regions of normal appearing white matter, helping to characterize the extent of injury.

Trajectory

- The trajectory of water molecules can be used to map the direction of diffusion in the brain.
- Modern DTI tracking algorithms can track water molecules through a selected region of interest, allowing for the visualization of white matter tracts.

Tractography

- DTI and tractography can be used to visualize the structural connectivity of the brain and the relationships between different regions.
- DTI and tractography can be used to identify abnormalities in the white matter tracts, such as in the case of stroke or multiple sclerosis.

Conclusion

DTI is a relatively new and exciting advanced magnetic resonance imaging technique that makes possible unprecedented characterization of the white matter tracts of the brain as well as a broad spectrum of neurophysiological processes. DTI and tractography are currently not broadly utilized, and there are technical limitations to overcome. However, this rapidly evolving technology is becoming increasingly available to many radiologists, and clinical imaging applications provide the radiologist and clinician with more precise insight into various neurophysiologic processes which may help better guide patient management.

Limitations

- Diffusion tensor imaging characterizes only the principal eigenvector but lacks information about the angular resolution to characterize anisotropic tissue.
- Current DTI tracking algorithms can only approximately estimate the orientation of diffusion in tissues.
- Current quantitative limitations of DTI tractography are conducive to obtaining an accurate representation of the white matter tracts.
- The fiber tracking algorithms make assumptions about the angular resolution of the diffusion coefficients which can not be verified in vivo.
- User-defined track propagation thresholds can limit reproducibility.