# Feasibility of DTI Assessment Using Capillary Phantoms: Initial Results

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## Introduction

Diffusion tensor imaging (DTI) techniques to map tissue fiber trajectories have great potential for clinical diagnosis and evaluation of a number of neurological conditions (1). However, no consensus exists for an appropriate assessment standard of DTI. Two current assessment techniques include the use of post-mortem neuroanatomical atlases (e.g., 2), which may have limited accuracy, or novel *in vivo* animal neural systems (e.g., 3), which may not be readily available at every site. The goal of this project is to determine the feasibility of using capillary bundles to construct a DTI assessment phantom. Diffusion within the capillaries will be simulated, and these results will be compared with fractional anisotropy (FA) maps calculated from DTI images of the phantom.

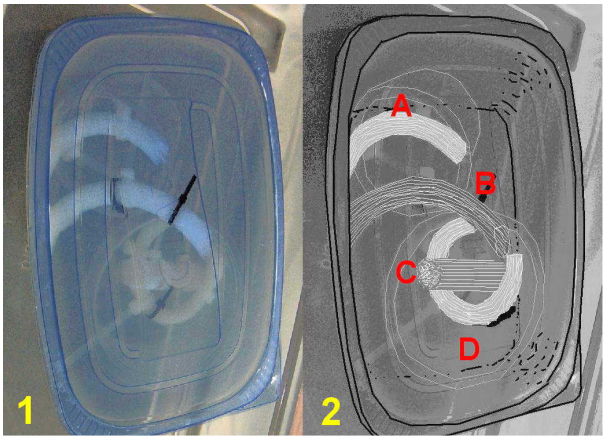


Fig. 1. Picture of phantom (panel 1), with annotation (panel 2) showing capillaries: A) small i.d. PTFE; B) larger i.d. PTFE; C) glass; D) Tygon.

## Methods

A Monte Carlo simulation of diffusion was performed, assuming an array of water-filled, close-packed cylinders. Coordinates were quantized into voxels, and diffusion of water molecules out of a voxel in a preferred direction was used to determine signal observed in a DTI scan.

A series of DTI images of a water-filled phantom were acquired for comparison with simulated FA results. The phantom (see Figure 1) consisted of a rectangular polypropylene container (~1.9 L) filled with ordinary tap water, containing four capillary bundles and two polypropylene cups used for support of these structures. Each capillary structure (~1cm in diameter) consisted of roughly one hundred pieces of tubing, filled with water by syringe injection and assembled during submersion under water, and bundled together tightly with standard nylon cable ties. The following bundles were constructed: 1) PTFE microbore capillaries with 0.012" i.d.; 2) PTFE capillaries with 0.022" i.d.; 3) Tygon capillaries with 0.01" i.d.; 4) microhematocrit glass capillary tubes with 0.8mm i.d.

The phantom was scanned in a GE Signa LX 1.5T scanner (GE Medical Systems, Milwaukee, WI), using a quadrature head coil. Two series of images (TR=5s / (image volume); 25 diffusion gradient directions, b=1000 s mm$^{-2}$) were acquired using a diffusion-weighted EPI sequence: a higher resolution scan (Acq. Matrix=128, NEX=1, TE=84 ms) and a lower resolution scan for optimal SNR (Acq. Matrix=64, NEX=2, TE=77.5 ms). FA and ADC maps were calculated on a GE workstation. Regions of interest (ROI) were defined using the b=0 reference images, eliminating the capillary bundle bounding regions.

## Results

Figure 2 shows FA and ADC values for the four capillary bundles as a function of capillary radius / mm$^{-2}$ on a log scale, averaged within the defined ROIs for each bundle. Error bars represent the standard deviation of the distribution of values from each ROI. Other systematic errors, such as the FA contribution from water in intrastitial space, need to be verified. Two other points located at the largest radius value on the plots correspond to values measured in two ROIs where water diffusion was unrestricted during the diffusion time. These values are arbitrarily plotted at r=4mm (one voxel at matrix=64), and displayed as a hatched region denoting a representative unrestricted range of values for FA and ADC. Data from the images having a larger matrix size were consistent with these results.

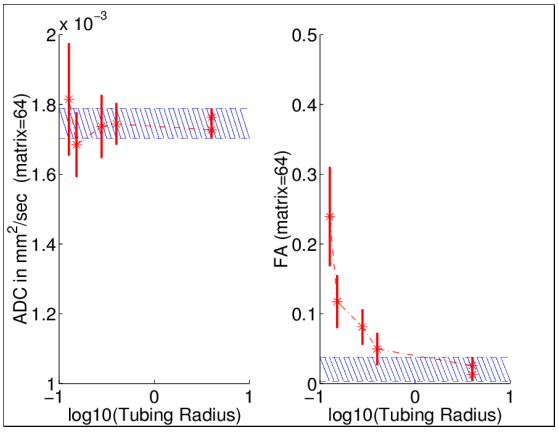


Fig. 2. ADC and FA values for capillary structures vs. capillary radius. The blue hatched region and points for largest radius represent values reported for two unrestricted

## Discussion

Note that all ADC values are self-consistent, and that the FA values increase with decreasing capillary size, as expected. This range of FA values is also in rough agreement with simulation results (0.05-0.2).

## References

1. Hagmann, P., et al. 2003. NeuroImage. 19: 545-554.
2. Tuch, D.S., et al. 2003. Neuron. 40: 885-895.
3. Lin, C.P., et al. 2001. NeuroImage. 14: 1035-1047.