Intervertebral Disc Diffusion

Jonathan Reuter; Won C Bae, PhD;
Nozomu Inoue, MD, PhD;
Robert L Sah, MD, ScD; Koichi Masuda, MD

2nd Symposium of the UCSD-Doshisha Medical Imaging Research Center

August 24th, 2010
Doshisha University, Kyoto, Japan

UCSD | Department of Bioengineering

University of California San Diego
Orthopaedic Surgery

Doshisha University
Biomedical Engineering

Project Motivation

- Low back pain is a very common and expensive musculoskeletal disorder.[1]
- Low back pain significantly decreases a person's quality of life.[1]
- One possible cause of low back pain is degeneration of the intervertebral discs.[2]
- Disc degeneration may result as a consequence of either insufficient transport through or ineffective solute regulation by the endplate.[3,4]

Low back pain

<http://www.tinker.com/event/RobertPubler/symptoms_of_low_back_pain/>

1. "Low Back Pain Fact Sheet." *National Institute of Neurological Disorders and Stroke*. National Institute of Neurological Disorders and Stroke, 07/2003. Web. 5 Apr 2010. <http://www.ninds.nih.gov/disorders/backpain/detail_backpain.htm>.

2. Mulholland, R C. (2007). "Scientific basis for the treatment of low back pain." Annals of the Royal College of Surgeons of England **89**(7): 677-81.

3. Roberts, S. P., J. P. G. P. Urban, et al. "Transport Properties of the Human Cartilage Endplate in Relation to Its Composition and Calcification." (0362-2436).

4. Grunhagen, T., G. Wilde, et al. (2006). "Nutrient Supply and Intervertebral Disc Metabolism." J Bone Joint Surg Am **88**(suppl_2): 30-35.

Project Outline

Goal

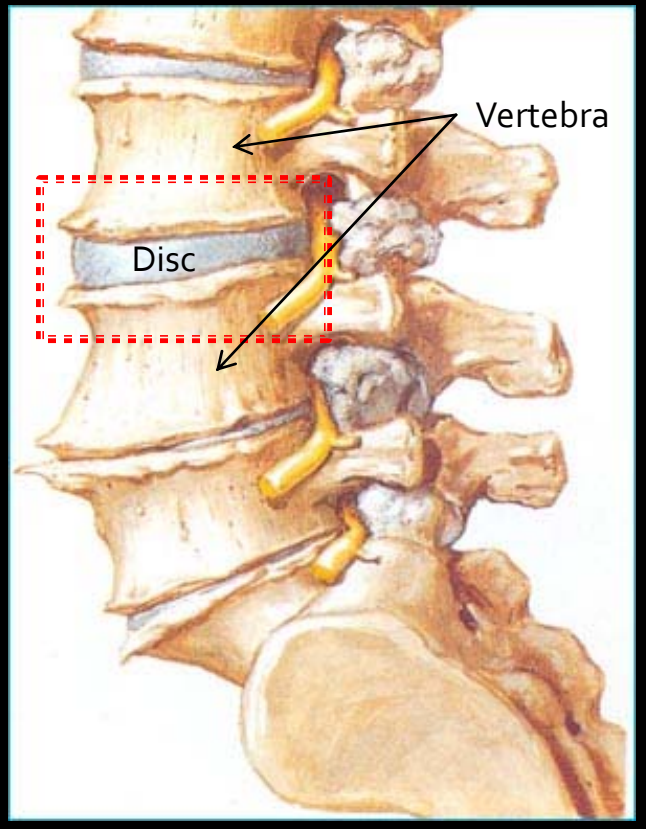
To determine the effect of aging on the transport properties of intervertebral disc in rabbit model.

Experiment

Micro-computed tomography and contrast agent were used to characterize *in vivo* diffusivity of rabbit endplate-disc-endplate complexes.

Analysis

A MATLAB program was developed to segment and analyze regions of interest over multiple time series images.



Endplate-disc-endplate complex

<http://www.shreejihospital.com/orthopaedics.html>

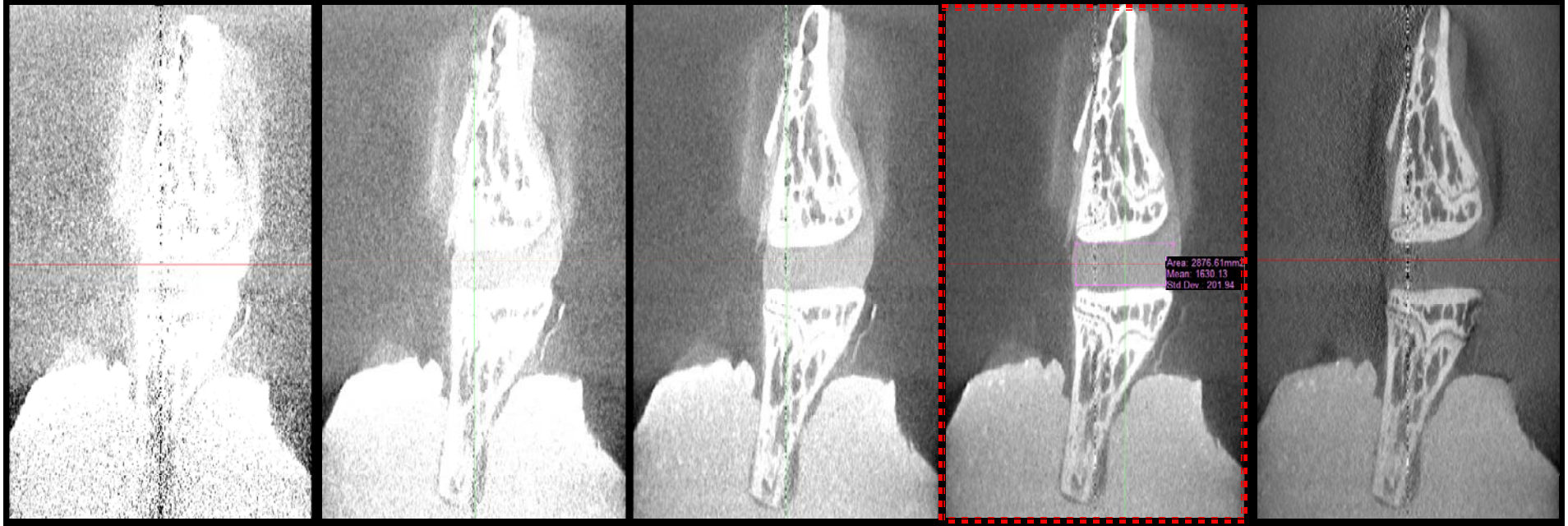
Scanning Methodology

- Samples: endplate-disc-endplate complexes segmented from New Zealand White rabbits.
- Device: Shimadzu X-Ray CT System SMX-160CTS.

Shimadzu X-Ray CT System SMX-160CTS

Voltage and Disc Density

Midline Sagittal Cross-Section

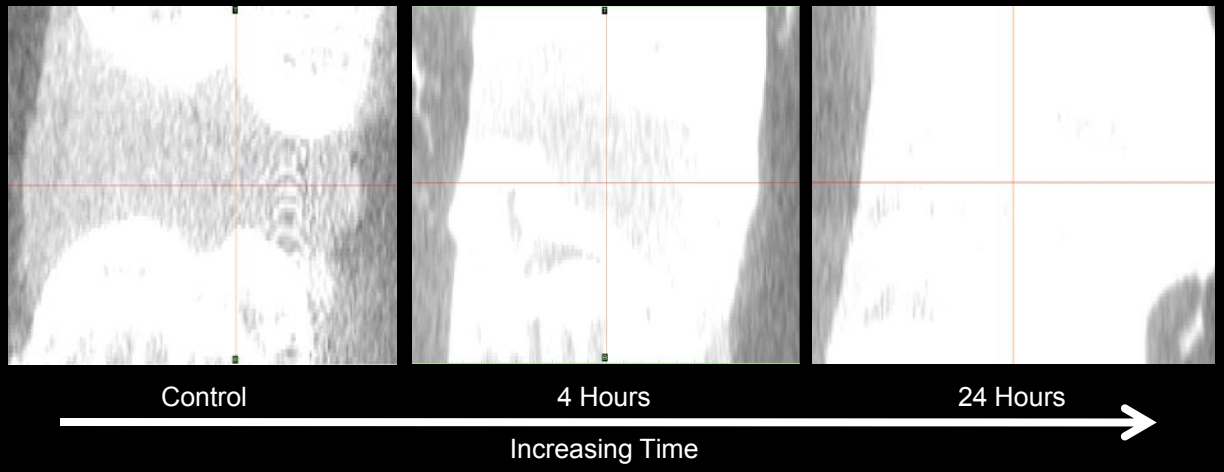


- ↑ Voltage correlates with ↓ density.
- ↑ Voltage correlates with ↑ standard deviation.

Contrast Agent Diffusion

Sample	Density (HU)
Bone	3035
Contrast	2983
Control	2479
4 Hours	2837
24 Hours	3005

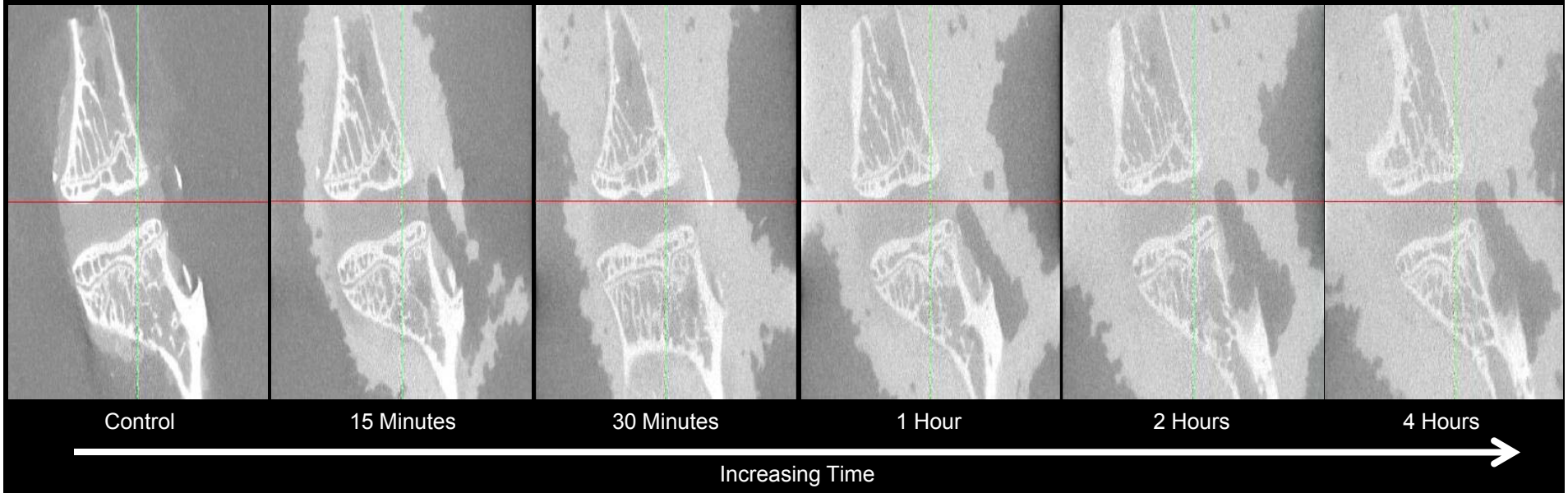
Midline Coronal Cross-Section



- Observed disc density reached 95% of contrast agent within 4 hours.
- After 24 hours, the disc became oversaturated with contrast agent and indistinguishable from the surrounding bone.
- Conclusion: shorter time course with more frequent scanning interval required.

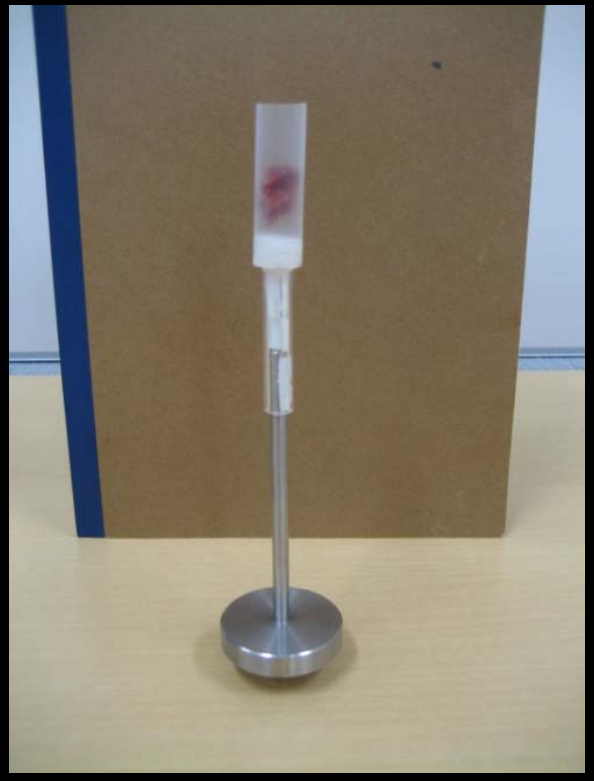
Contrast Agent Diffusion

Midline Sagittal Cross-Section



- Once again, the disc becomes indistinguishable from its surrounds after 4 hours.
- Note: contrast agent was absorbed by the holding chamber sponge resulting in noise.

Sample Holding Chamber



1st Prototype

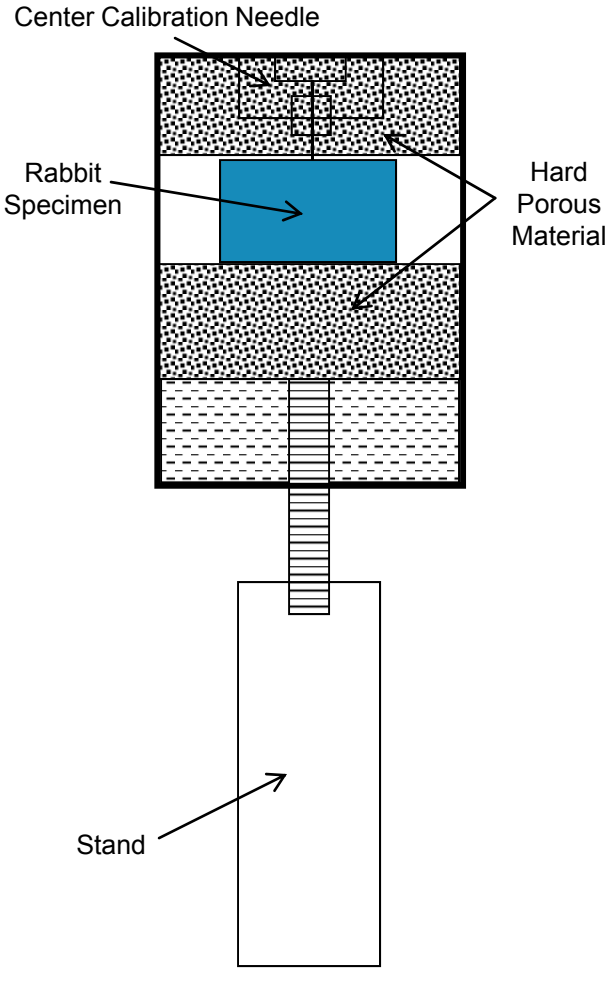
2st Prototype

Production Model

- Scanning environment: wet vs. dry.
- Stabilization of both chamber and sample.

Design Improvements

- Replace holding sponge with hard, porous, non-absorbing material in order to reduce surrounding noise and ensure proper orientation of sample.
- Include syringe to drain and fill chamber with contrast agent without disturbing sample.
- Stack samples in sandwich fashion in order to scan multiple levels at the same condition using a single center calibration.
- Utilize second PC to scan and reconstruct simultaneously.



Courtesy of Inoue Sensei

Experiment and Analysis in Parallel

Experiment

Micro-computed tomography and contrast agent were used to characterize *in vivo* diffusivity of rabbit endplate-disc-endplate complexes.

Analysis

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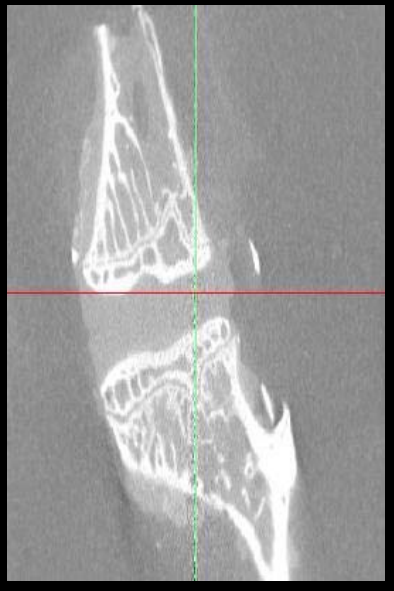
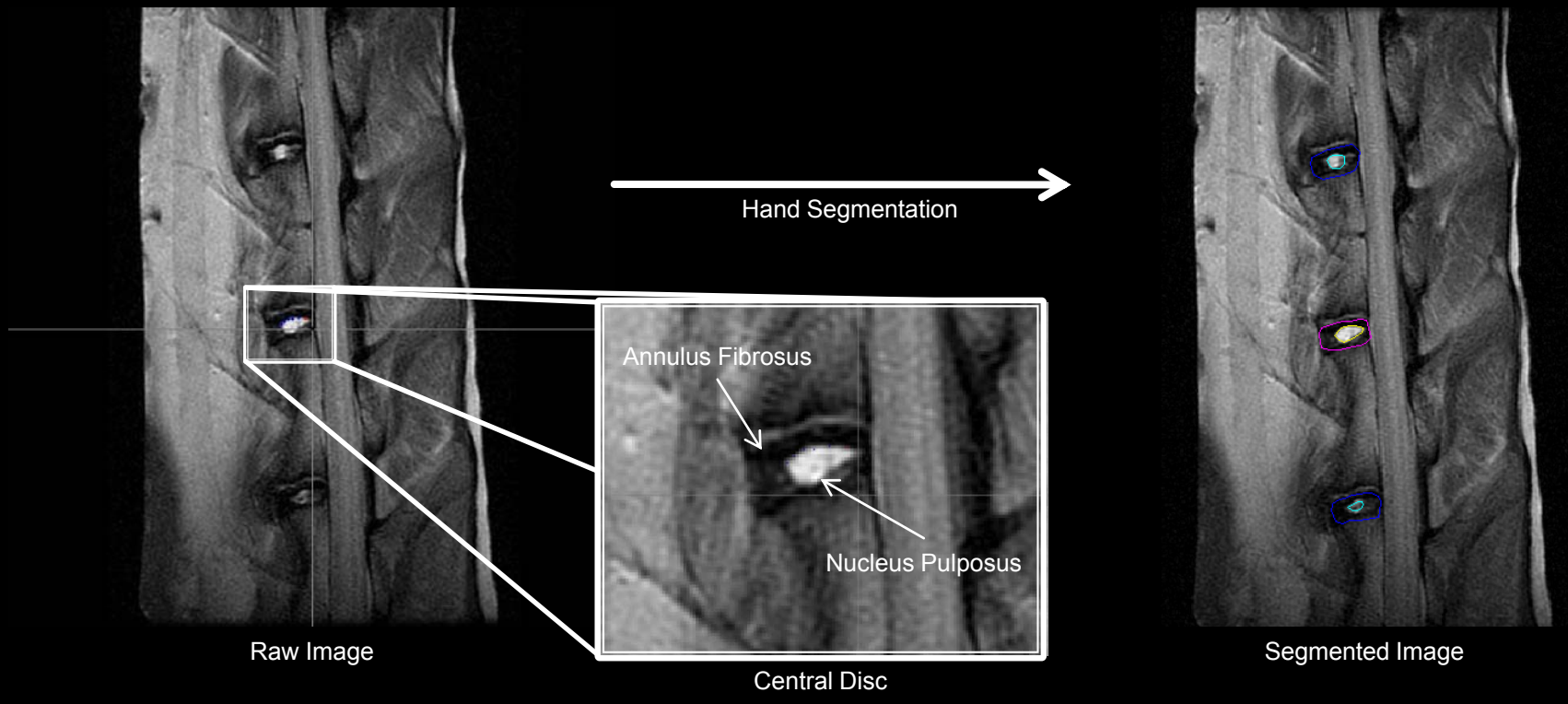


Contrast Enhanced micro-CT Rabbit Endplate-Disc-Endplate Complex

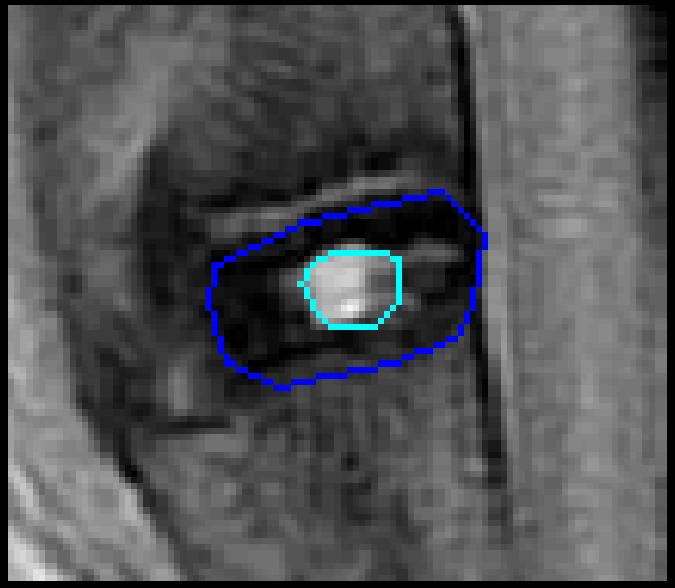
MRI T2 Weighted Human Spine

Hand Segmentation

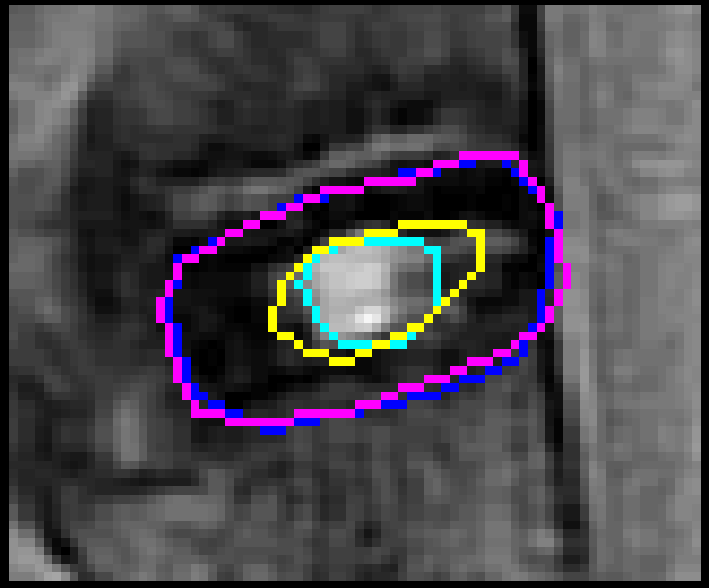


- The annulus fibrosus and nucleus pulposus of each disc were hand segmented using simple polygonal geometries.

Rigid Transformation

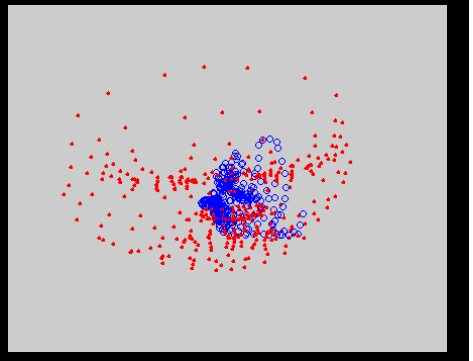


Hand Segmentations



Transformed Segmentations

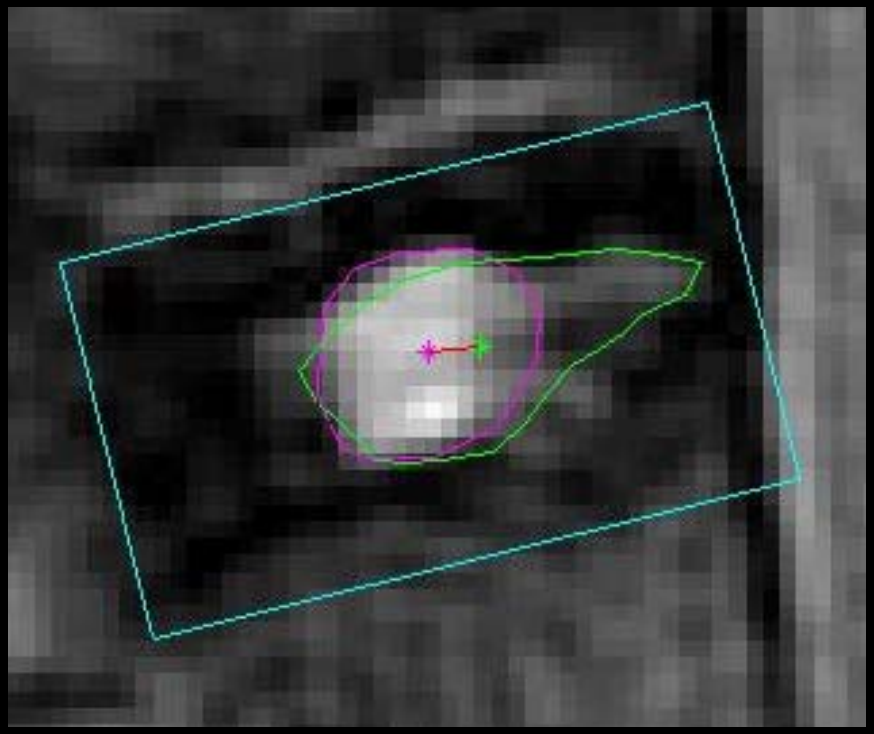
- Using the middle disc as a “healthy” reference, segmentations for the top and bottom discs were generated using rigid transformations.
- The hand segmented annulus fibrosus served as references for the transformations.



Rigid Transformation Example

< http://www.bme.ogi.edu/~myron/matlab/cpd/ >

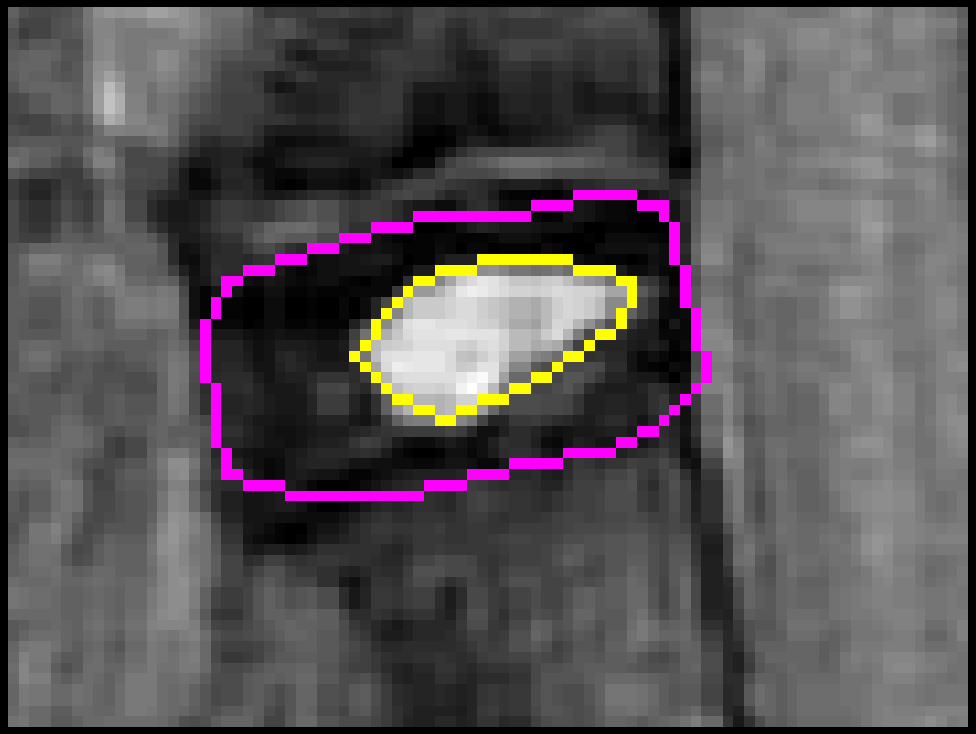
Centroid Correction



Centroid Correct Using Hand Segmentation

- Transformed nucleus pulposus segmentations were centroid corrected using hand segmentations.

Signal Intensity



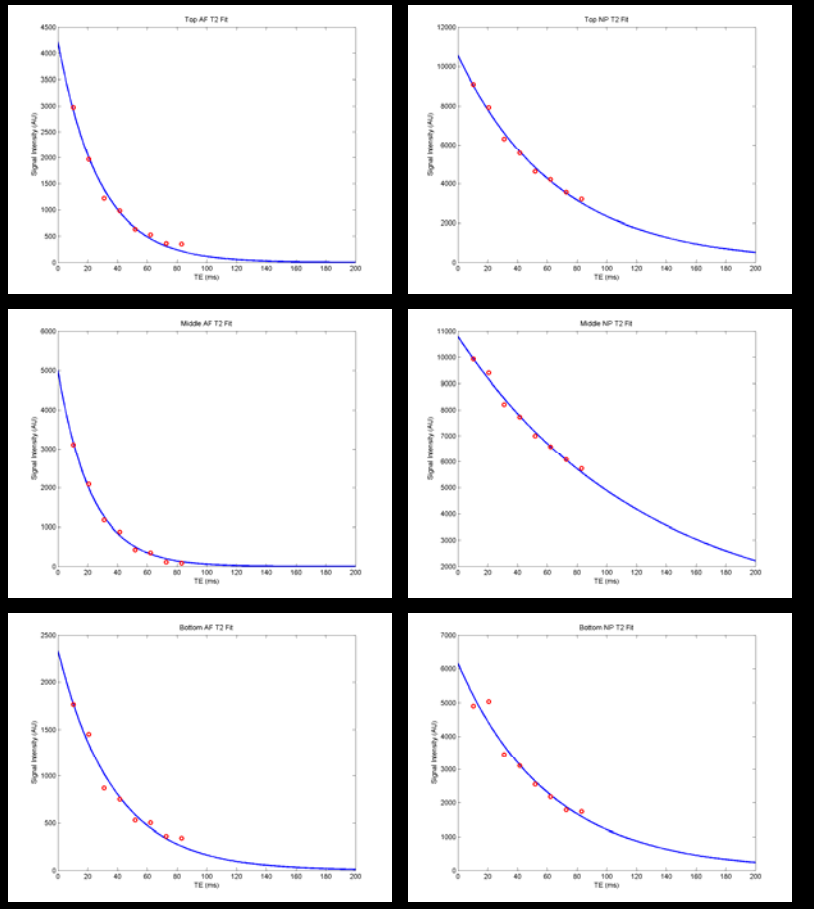
Signal Intensity of Segmentations

- Signal intensity was calculated by multiplying the average signal intensity times the segmentation area.

Applications

- MRI: the disc signal intensity was measured for multiple time points using the same segmentations. The results fit the characteristic exponential decay of signal. Parameters from this fit can be used to determine material properties of the disc (T2 mapping).
- Micro-computed tomography and contrast agent : using a similar method we hope to measure the regional diffusivity of contrast agent into the disc.

Exponential Decay of Signal Intensity



Annulus Fibrosus | Nucleus Pulposus

Acknowledgments

Laboratories and People

-Prof. Nozomu Inoue, Tissue Engineering Lab, Doshisha University
-Prof. Koichi Masuda, Skeletal Translational Research Lab, UC San Diego
-Prof. Noriko Koizumi, Research Center for Inflammation and Regenerative Medicine, Doshisha University
-Prof. Robert L Sah, Cartilage Tissue Engineering Lab, UC San Diego
-Dr. Gabriele Wienhausen, Associate Dean of Education, Division of Biology, UC San Diego
-Dr. Peter Arzberger, Principal Investigator, Pacific Rim Application and Grid Middleware Assembly (PRAGMA)
-The Students of the Tissue Engineering Lab at Doshisha University

Programs and Supporting Agencies

-Department of Biomedical Engineering, Doshisha University
-Pacific RIM undergraduate Experience, UC San Diego
-California Institute for Telecommunications and Information Technology
-National Science Foundation, IOSE-0710726

Questions