RESPONSIVENESS OF A SEMI-AUTOMATED NOVEL METHOD OF MEASURING CARTILAGE LOSS IN KNEE OSTEOARTHRITIS OVER TWO YEARS USING 3T DESS 3D MRI.

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Motivation (OAI)

• 38,337 individual 3D (DESS pulse sequence) MRI scans (BL - 48mo)
• These need to be read at some point.
• Assuming 1 hour/scan, total reader time is 24 years!
• Goal: Substantially reduce the reader time.
• At 5 minutes/knee...2 years total time.
Location-specific joint space width (JSW)

Locations are relative to the knee (dimensionless)
Advantages of location Specific JSW

- Consistent definition of space for cross sectional and longitudinal studies
- Look at other structural measures (e.g. ROIs for bone texture measures)
- No need to fully delineate joint margins.
Measure in a limited region

Local-area cartilage segmentation (LACS)
Cylindrical coordinate system

\( \{z=0, r=0; \theta=0^\circ \} \)
Cylindrical coordinate system

\[ \{z=3, r=0, \theta=0^\circ\} \]

Cylindrical coordinate system

\[ \{z=3, r=1, \theta=0^\circ\} \]
Cylindrical coordinate system

\( \{z=3, r=2, \theta=0^\circ\} \)

Cylindrical coordinate system

\( \{z=3, r=3, \theta=0^\circ\} \)
Cylindrical coordinate system

\( z = 3, \ r = 3, \ \theta = 30^\circ \)

Cylindrical coordinate system

\( z = 1, \ r = 1, \ \theta = 60^\circ \)
Cylindrical coordinate system

\( z=3, \ r=3, \ \theta=90^\circ \)
Define $z=0$, $z=1.0$

$\theta$ coordinate

- $\theta = 0^\circ$
- $\theta = 90^\circ$
- $\theta = 180^\circ$
- $\theta = 210^\circ$
Location specific MRI
Specify by $z_0$, $Δz$, $θ_0$, and $Δθ$.

$z_0 = 0.8$, $Δz = 0.1$
$θ_0 = 200°$, $Δθ = 50°$

Slice segmentation
Validation Study

• 24 subjects: OAI Progression Cohort (Data Set 0.1.1 and Image Releases 0.B.1 and 1.B.1.)
• K/L score of 3
• Time points: Baseline and 24 month visits.
• Pulse sequence: Siemens Trio 3T scanner using 3D DESS with water excitation
• Reader was blinded to time point.

Responsiveness measures:

• Average volume change ($\Delta V$)
• Standard deviation of volume change (SD)
• Standardized response means
  $SRM=\Delta V/SD$
Results (SRM values)

\[ z_0 = 0.8, \ \theta_0 = 210^\circ \]

<table>
<thead>
<tr>
<th>( \Delta z )</th>
<th>( \Delta \theta )</th>
<th>SRM</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10</td>
<td>100(^\circ)</td>
<td>-0.71</td>
</tr>
<tr>
<td>0.08</td>
<td>80(^\circ)</td>
<td>-0.66</td>
</tr>
<tr>
<td>0.06</td>
<td>60(^\circ)</td>
<td>-0.55</td>
</tr>
<tr>
<td>0.04</td>
<td>40(^\circ)</td>
<td>-0.60</td>
</tr>
<tr>
<td>0.02</td>
<td>20(^\circ)</td>
<td>-0.39</td>
</tr>
</tbody>
</table>

Results

• Method is fast: ~ 10 minutes/knee for the skilled reader
• Only a sub region requires attention
• Reader only has to segment a limited number of slices
• Excellent responsiveness for smaller region \((\Delta z = 0.04, \ \Delta \theta = 40^\circ)\) implies an even faster method.
• **Limitation:** probes a single region
Analysis model #2
Sample multiple fixed locations

Conclusions

• Use of robust coordinate system provides responsive measure of cartilage change
• Method is fast. Potential to assess over 1,000 knees.
• Can be used to quantify additional structures
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Conclusions

General 3D gray scale intensity function to characterize every voxel in the image set.

\[ I = f(z, \theta, r) \]
Analysis model #3

(Future study)

Pick an indexed location for each knee individually.