Central Assessments of MRI Images for Quantitative Measurements of Cartilage Morphology from knee MRI Scans (Felix Eckstein: Chondrometrics and Paracelsus)

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1. Overview

1.1 SAS dataset
   Name: kMRI_QCart_EcksteinXX (XX identifies the time point)
   Display label: kMRI quantCartilage (Eckstein)

1.2 Contents of dataset
   This dataset contains centrally performed measurements of cartilage volume and thickness from serial
   knee MRI scans performed by Felix Eckstein’s group in Germany (Chondrometrics, Gmbh, Ainring) or
   Austria (Paracelsus University, Salzburg) http://www.chondrometrics.com/. The data from more than one
   project by this vendor are contained in the data set.

   Each dataset contains the reading data for a single visit or time point. The corresponding longitudinal data
   from reading projects by this vendor for other time points are in separate datasets. For example, the data
   from this vendor’s reading of baseline MRIs are in a dataset ending in “00” (i.e., kMRI_QCart_Eckstein00),
   while the corresponding data from this vendor for the 12-month visit MRI readings are in a dataset with the
   same name but ending in “01” (i.e., kMRI_QCart_Eckstein01), and so on. (See the document
   “VisitPrefixDefinitions.pdf” document in the image assessments section of OAI Online,
   http://www.oai.ucsf.edu/datarelease/ImageAssessments.asp, for a guide to visit numbering). To compare
   values of a variable across time points from a given project by this vendor, or to calculate change scores,
   users will need to merge the datasets for the various time points.

   IMPORTANT: All users are strongly encouraged to read the Overview and Description of Central
   Image Assessments document carefully before attempting to use this dataset!

   For comprehensive and detailed information about the structure and contents of the central image
   assessment datasets, general guidelines for defining change between time points and duration of follow-up,
   and strategies for merging datasets for analysis, please see the “Overview and Description of Central
   Image Assessments” link found in the image assessments section of OAI Online,
   http://www.oai.ucsf.edu/datarelease/ImageAssessments.asp. This document is also located in the compressed
documentation file (.zip) that accompanies the corresponding compressed dataset file (.zip).

1.3 Condition
   • Known data errors: problems/cautions for use are listed by variable in the “Release Comments”,
     which can be found in the various kMRI_QCart_EcksteinXX_Comments.pdf files which are located
     in the compressed documentation (.zip) that accompanies the corresponding dataset file. Release
     comments can also viewed in Search/Browse, the online database, at
     http://www.oai.ucsf.edu/datarelease/ldd.asp.

     • There have been some minor modifications to the data for Projects 09A and 09B. Over the course
     of those projects, there were some updates to the software which processed the outlines of the
     articular cartilage and converted them into measurements of volume, thickness and area. Since the
     previous release of the kMRI_QCart_EcksteinXX datasets (on 5/9/2011, versions 0.4, 1.4, 3.4, 6.3)
     all of the outlines of articular cartilage have been reprocessed using the latest version of the
     software, to ensure that data for all knees at all time points were handled in the same way. The
     changes to the previously released data are insignificant, and were no larger than +0.06mm for
     cartilage thickness of the main cartilage plates (which typically have mean thickness around 1.5 to
     2.0mm), and +42mm$^3$ for cartilage volume of the main cartilage plates (which typically have
     volumes of 1000-2000 mm$^3$). The changes have affected only the baseline, 12-month and 24-month
     visit measurements for the first 107 participants analyzed for Project 09A/B.

   • Dataset strengths/weaknesses:
     o Data are expected for all participants included in a project sample. If expected data do not
       exist for a knee, SAS special missing values are assigned to denote why the data were not
       obtained.
The dataset may include multiple rows of data (records) for a given knee which needs to be taken into account when merging it with other datasets. Please see the “Overview and Description of Central Image Assessments” link in the image assessments section of OAI Online, http://www.oai.ucsf.edu/datarelease/ImageAssessments.asp, for more information on merging.

To examine longitudinal changes in cartilage morphology measurements for a specific project, records for that project in the kMRI_Qcart_Eckstein00 datasets are used for baseline visit values, and then longitudinal changes from those values are found by using values of the same variable in the follow-up kMRI_Qcart_EcksteinXX datasets which have the same values for ID, SIDE and READPRJ.

1.4 Variables and reading methods
See the dataset documentation file kMRI_QCart_EcksteinXX_Contents.pdf in the compressed documentation file for a complete list of all the variables in the dataset, their SAS variable names, descriptive variable labels and attributes.

Missing data can occur for a variety of reasons. In the individual kMRI_Qcart_EcksteinXX datasets, SAS special missing values are used to indicate the following:

\- P if data is missing due to a prosthesis/knee replacement
\- T if data is missing due to technical reasons
\- A if the data is not expected

Missing data can also occur after merging data from different visits. For example, a participant may have V00… and V03… measurements but if that person did not attend their 12-month visit, they would have no data in the kMRI_Qcart_Eckstein01 dataset, but in a merged dataset containing longitudinal data from baseline, 12-month and 24-month visits, that participant would have missing values for their V01… variables.

The image analysis and measurement techniques used are similar in the different projects by this vendor, and are outlined below. Any modifications for a specific project are described in the section related to that project, including:

\- differences in the regions of cartilage analyzed
\- the types of MRI pulse sequences used
\- criteria for selecting the knees to analyze

1.4a Technique for segmenting articular cartilage from the MR images
Measurements of volumes, thickness and areas of articular cartilage and subchondral bone are provided and are for a specific anatomic location in the knee (cartilage plates and/or subregions).

These publications give more details about the methods used by Felix Eckstein’s group (Chondrometrics GmbH, Ainring, Germany and Paracelsus University, Salzburg, Austria) for generating the data in these datasets:


The following brief overview of the methods uses standard labeling nomenclature for describing MRI-based measures of articular cartilage in OA:

- the anatomical location (cartilage plates and their subregions) in the knee (e.g. MT for entire medial tibia)
- the structural feature being measured, consisting of a metric and a tissue label (e.g. ThCTAB for cartilage thickness over the entire subchondral bone area)
- when relevant, computational and statistical aspects of the structural metric (e.g. cartilage thickness in a specific location could be described by a mean value, a minimum value, a maximum value or a standard deviation)

These publications are recommended for further explanation of the standard labeling nomenclature:


The main cartilage plates and subregions are outlined below and shown in figures 1 and 2.

1.4b Main cartilage plates
This table shows the cartilage plates analyzed for coronal MRI images (also see Figure 1).

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MT</td>
<td>medial tibia [BLUE in Fig. 1]: entire cartilage plate, analysis of all slices in which MT is depicted</td>
</tr>
<tr>
<td>cMF</td>
<td>central (weight-bearing) part of medial femoral condyle [YELLOW in Fig. 1]</td>
</tr>
<tr>
<td>LT</td>
<td>lateral tibia [GREEN in FIG. 1]: entire cartilage plate, analysis of all slices in which LT is depicted</td>
</tr>
<tr>
<td>cLF</td>
<td>central (weight-bearing) part of lateral femoral condyle [RED in Fig. 1]</td>
</tr>
</tbody>
</table>

Note: the definition of the central (weight bearing) part of femoral condyles is given in: Eckstein F, et al. Double echo steady state magnetic resonance imaging of knee articular cartilage at 3 Tesla: a pilot study for the Osteoarthritis Initiative. Ann Rheum Dis 2006;65:433-441); and represents 60% of the slices between the trochlear notch (anteriorly) and the posterior end of the femoral condyles. [http://ard.bmj.com/cgi/content/abstract/65/4/433]
The following table shows the main cartilage plates analyzed for sagittal MR images (also see Figure 2).

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MT</td>
<td>medial tibia [BLUE in Fig. 2, top]: entire plate, analysis of all slices in which MT is depicted</td>
</tr>
<tr>
<td>MF</td>
<td>entire medial femoral condyle</td>
</tr>
<tr>
<td>cMF 60%</td>
<td>central (weight-bearing) medial femoral condyle defined based on 60% of the distance between trochlear notch and posterior end of femoral condyle</td>
</tr>
<tr>
<td>cMF 75%</td>
<td>central (weight-bearing) medial femoral condyle defined based on 75% of the distance between trochlear notch and posterior end of femoral condyle</td>
</tr>
<tr>
<td>pMF 60%</td>
<td>posterior medial femoral condyle defined based on 60% of the distance between trochlear notch and posterior end of femoral condyle</td>
</tr>
<tr>
<td>pMF 75%</td>
<td>posterior medial femoral condyle defined based on 75% of the distance between trochlear notch and posterior end of femoral condyle</td>
</tr>
<tr>
<td>LT</td>
<td>lateral tibia [GREEN in FIG. 2, top]: entire plate, analysis of all slices in which LT is depicted</td>
</tr>
<tr>
<td>LF</td>
<td>entire lateral femoral condyle</td>
</tr>
<tr>
<td>cLF 60%</td>
<td>central weight-bearing lateral femoral condyle defined based on 60% of the distance between trochlear notch and posterior end of femoral condyle</td>
</tr>
<tr>
<td>cLF 75%</td>
<td>central weight-bearing lateral femoral condyle defined based on 75% of the distance between trochlear notch and posterior end of femoral condyle</td>
</tr>
<tr>
<td>pLF 60%</td>
<td>posterior lateral femoral condyle defined based on 60% of the distance between trochlear notch and posterior end of femoral condyle</td>
</tr>
<tr>
<td>pLF 75%</td>
<td>posterior lateral femoral condyle defined based on 75% of the distance between trochlear notch and posterior end of femoral condyle</td>
</tr>
</tbody>
</table>

Note: there are two definitions used to separate the central (weight bearing) portion of a femoral condyle from the posterior of the condyle. **The 60% definition is similar to that used for coronal MRI image analysis.** To determine which (if any) definition a specific project uses, see the project-specific sections at the end of this document.
Figure 1: Cartilage plates analyzed in coronal images.

**Top Row:** The left image shows a FLASHwe image without labeling of the cartilage plates, the right image shows the same FLASHwe images with cartilage plates labeled:

- MT = medial tibia
- cMF = central (weight-bearing) medial femoral condyle
- LT = lateral tibia
- cLF = central (weight-bearing) lateral femoral condyle

**Bottom Row:** The images show 3D reconstructions with the bones segmented and the cartilage plates depicted in the same color as in the upper row.

---

**Top Row:** The left images shows a FLASHwe image without labeling of the cartilage plates, the right image shows the same FLASHwe images with cartilage plates labeled:

- MT = medial tibia
- cMF = central (weight-bearing) medial femoral condyle
- LT = lateral tibia
- cLF = central (weight-bearing) lateral femoral condyle

**Bottom Row:** The images show 3D reconstructions with the bones segmented and the cartilage plates depicted in the same color as in the upper row.
Figure 2: Cartilage plates analyzed in sagittal images.

**Top Row:** The images show 3D reconstructions of the cartilage plates:

- MT = medial tibia = blue
- MF = medial femoral condyle = yellow
- LT = lateral tibia = green
- LF = lateral femoral condyle = red

**Bottom Row:** The images show sagittal MR images (DESSwe sequence) with the cartilage of MF being divided (turquoise line) into cMF and pMF at 60% (left) and 75% (right) of the distance between the trochlear notch (magenta colored line) and the posterior end of the femoral condyle (blue line). Note that the magenta colored line is oriented parallel to the femoral shaft and through the trochlear notch in a central slice between MF and LF (not in the slice shown here) and that the posterior ends of MF and LF are determined in slices depicting the most posterior aspects of MT and LF, respectively.
1.4c Subregions of main cartilage plates
This table shows the subregions analyzed in the medial tibio-femoral condyle cartilage plates (also see Figure 3) for analysis of both coronal and sagittal images:

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cMT</td>
<td>central subregion of medial tibia (20% of tAB) *</td>
</tr>
<tr>
<td>eMT</td>
<td>external subregion of medial tibia</td>
</tr>
<tr>
<td>iMT</td>
<td>internal subregion of medial tibia</td>
</tr>
<tr>
<td>aMT</td>
<td>anterior subregion of medial tibia</td>
</tr>
<tr>
<td>pMT</td>
<td>posterior subregion of medial tibia</td>
</tr>
<tr>
<td>ccMF</td>
<td>central subregion of central (weight-bearing) medial femur (33% of tAB)</td>
</tr>
<tr>
<td>ecMF</td>
<td>external subregion of central (weight-bearing) medial femur (33% of tAB)</td>
</tr>
<tr>
<td>icMF</td>
<td>internal subregion of central (weight-bearing) medial femur (33% of tAB)</td>
</tr>
<tr>
<td>cMFTC</td>
<td>central medial femoro-tibial compartment *</td>
</tr>
</tbody>
</table>

* see next section for definition of tAB
* this subregion is an aggregate of values for cMT and ccMF (cMT + ccMF)

An analogous set of subregions is analyzed in the lateral tibio-femoral cartilage plates (also see Figure 3).

This table shows the subregions analyzed in sagittal MR images of the medial femoral condyle cartilage plate (also see Figure 3).

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cpMF</td>
<td>central subregion of posterior medial femur (33% of tAB)</td>
</tr>
<tr>
<td>epMF</td>
<td>external subregion of posterior medial femur (33% of tAB)</td>
</tr>
<tr>
<td>ipMF</td>
<td>internal subregion of posterior medial femur (33% of tAB)</td>
</tr>
</tbody>
</table>

An analogous set of subregions is analyzed in sagittal MR images of the lateral femoral cartilage plate (also see Figure 3).
Figure 3: Subregions of tibio-femoral cartilage plates.

Top Row: Subregions of MT, LT, cMF and cLF, view from anterior
Middle Row: Subregions of MT & LT, view from superior
Bottom Row: Subregions of cMF & cLF, view from inferior
1.4d Structural features and metrics
This table shows the measurements of structural features and metrics provided for various cartilage plates and subregions (also see Figure 4).

<table>
<thead>
<tr>
<th>Label</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC</td>
<td>(mm$^3$)</td>
<td>cartilage volume (computed by numerical voxel integration)</td>
</tr>
<tr>
<td>tAB</td>
<td>(cm$^2$)</td>
<td>total area of subchondral bone</td>
</tr>
<tr>
<td>AC</td>
<td>(cm$^2$)</td>
<td>area of cartilage surface</td>
</tr>
<tr>
<td>cAB</td>
<td>(cm$^2$)</td>
<td>area of subchondral bone covered by cartilage</td>
</tr>
<tr>
<td>dAB%</td>
<td>(%)</td>
<td>% area of subchondral bone denuded of cartilage</td>
</tr>
<tr>
<td>VCltAB</td>
<td>(mm)</td>
<td>cartilage volume divided by tAB (normalized cartilage volume)</td>
</tr>
<tr>
<td>ThCtAB</td>
<td>(mm)</td>
<td>cartilage thickness over tAB</td>
</tr>
<tr>
<td>ThCcAB</td>
<td>(mm)</td>
<td>cartilage thickness over cAB</td>
</tr>
</tbody>
</table>

Note: volumes have been computed by numerical voxel integration and not after surface reconstruction in cases where cAB = tAB (no denuded area present), ThCcAB = ThCtAB.

1.4e Computational details for cartilage thickness (ThC) metrics
Cartilage thickness measurements are summaries of the metric over a specific area of a cartilage plate or a subregion. These summaries can be calculated in several different ways. The bold portion of the description is used in our documentation and is related to the short abbreviated form used in various Eckstein publications, as outlined below.

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>aMe</td>
<td><strong>mean cartilage thickness</strong> = the algorithm computes the average of two distances: distance from AC to tAB (c) and from tAB to AC (b), respectively.</td>
</tr>
<tr>
<td>aMiv</td>
<td><strong>minimum cartilage thickness</strong> = mean of the 1% of lowest thickness values over a given area. Because in all peripheral regions the cartilage thickness drops off to zero at the margins, this variable is used only for cMT, ccMF, cLT and ccLF. The reason for not taking a single minimal measurement (min), but an average (1% lowest values in region) is the higher precision of Miv versus Min.</td>
</tr>
<tr>
<td>aMav</td>
<td><strong>maximum cartilage thickness</strong> = mean of the 1% of highest thickness values over a given area. The reason for not taking a single maximal measurement (max), but an average (1% highest values in region) is the higher precision of Mav versus Max</td>
</tr>
<tr>
<td>SD</td>
<td><strong>SD of cartilage thickness</strong> = standard deviation of cartilage thicknesses over a given area. This is a measure of the variation in cartilage thickness over a given area.</td>
</tr>
<tr>
<td>CV</td>
<td><strong>CV% of cartilage thickness</strong> = coefficient of variation of cartilage thickness over a given area. This is a measure of the variation in cartilage thickness over a given area, i.e. CV% = 0 = uniform cartilage thickness.</td>
</tr>
</tbody>
</table>

Note: other OAI datasets may use similar descriptions (e.g.: “mean cartilage thickness” or “minimum cartilage thickness”) and although the measurements may be similar, differences in the algorithms used to calculate them should be taken into account when comparing techniques and measurements.
Figure 4: Subregions of tibio-femoral cartilage plates illustrating the various measurements.

The left image shows segmentations of the AC (magenta) and of the tAB (green) and how the tAB is separated by AC into cAB and dAB.

Please note that in cases where AC covers the entire tAB (no denuded area) cAB is equal to tAB. Cartilage thickness (ThC) may be computed for the cAB only (ThCcAB) or over the entire tAB (ThCtAB), with the dAB being included as 0 mm cartilage thickness.

In cases where cAB = tAB (no denuded area present), ThCcAB = ThCtAB.
1.4f. SAS variable names
See the dataset documentation file kMRI_QCart_EcksteinXX_Contents.pdf in the compressed documentation file for a complete list of all the variables in the dataset, their SAS variable names, descriptive variable labels and attributes.

The SAS variable names used in OAI datasets are limited to 10 characters and cannot incorporate the complete standard nomenclature labels for anatomical location, measurement parameters and computational modifiers outlined previously.

SAS variable names in this dataset follow these conventions:
- the first part of the name specifies which visit the data belong to (e.g. V00 = baseline visit)
- the middle section of the name defines the anatomical location (e.g. MT = medial tibia) and/or subregion (e.g. CMT = central medial tibia)
- the ending of the name defines the structural feature/metric. (e.g. VCL = volume of cartilage)

For this dataset, the following table shows the relationship between the end of the SAS variable name and its corresponding structural feature. Both the standard nomenclature label and the variable description are included in the SAS descriptive variable labels, which give good descriptions of the data stored in a specific variable.

<table>
<thead>
<tr>
<th>Ending of SAS Variable Name</th>
<th>Structural features and metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Label(^1)</td>
</tr>
<tr>
<td>VCL</td>
<td>VC</td>
</tr>
<tr>
<td>SBA</td>
<td>tAB</td>
</tr>
<tr>
<td>ACS</td>
<td>AC</td>
</tr>
<tr>
<td>CAAB</td>
<td>cAB</td>
</tr>
<tr>
<td>PD</td>
<td>dAB%</td>
</tr>
<tr>
<td>VCN</td>
<td>VClAB</td>
</tr>
<tr>
<td>MTH</td>
<td>ThCtAB.aMe</td>
</tr>
<tr>
<td>MTC</td>
<td>ThCcAB.aMe</td>
</tr>
<tr>
<td>MAV</td>
<td>ThCtAB.aMav</td>
</tr>
<tr>
<td>MAT</td>
<td>ThCtAB.aMiv</td>
</tr>
<tr>
<td>CTS</td>
<td>ThCtAB.aSD</td>
</tr>
<tr>
<td>ACV</td>
<td>ThCtAB.aCV</td>
</tr>
</tbody>
</table>

\(^1\) Label proposed in Eckstein F et al. Proposal for a nomenclature for magnetic resonance imaging based measures of articular cartilage in osteoarthritis. Osteoarthritis Cartilage 2006;14:974-983. [http://dx.doi.org/10.1016/j.joca.2006.03.005](http://dx.doi.org/10.1016/j.joca.2006.03.005) (3)

Note: Section 1.4e describes the differences and methods of calculating the different cartilage thickness metrics

Also note that not all structural features exist for each anatomical location and not all anatomical locations are analyzed for all the projects in this dataset, so some records will have missing values.
2. Methods specific to Project 04 (Image Group B) – sponsored by Pfizer, Inc, a private partner of the OAI

2.1 Image type:
Coronal MRI (FLASH water excitation sequence) of the right knee (1.5mm slice thickness, 0.31mm in-plane pixel size). For the MRI acquisition protocol, see the “MRI Manual” link in the operation manuals section of OAI Online at http://www.oai.ucsf.edu/datarelease/OperationsManuals.asp.

2.2 Time points:
Baseline and 12-month visits.

2.3 Measurement methods:
The images were assessed paired and blinded to chronological order. The technique used is the same as for Projects 07, 08, and 9B. Details are published: http://ard.bmj.com/cgi/content/abstract/ard.2008.089904v2

For Project 04, the femoral regions (cMF and cLF) were defined using 60% of the distance between the trochlear notch and the posterior of the femoral condyle (see Figure 2 above).

2.4 Variables:
Tibio-femoral compartment cartilage volume, area, and thickness parameters and bone area parameters for medial tibia, lateral tibia weight bearing medial femur and weight bearing lateral femur plates and associated subregions. No posterior femoral regions were analyzed since coronal orientation MRI images were analyzed. Patello-femoral cartilage was not analyzed.

2.5 Sample:
Subjects were in Image Group B, which is a sample of 160 Progression subcohort participants (Image releases 0.B.1 and 1.B.1).

By virtue of being in the Progression subcohort, at baseline these 160 participants had symptomatic OA in at least one knee, defined as the combination of definite osteophytes (OARSI atlas grade 1-3, based on the OAI clinical center screening reading) and in the same knee, frequent knee symptoms.

Participants were selected for Image Group B if they:
- were among the 1,383 for whom a clean set of baseline images was delivered to the Coordinating Center from the OAI Imaging QA center (Synarc, Inc) on 4/14/06
- were assigned to the Progression subcohort
- had the following at baseline:
  - Accepted* fixed-flexion knee radiograph
  - Accepted’ three key MRI sequences (SAG 3D DESS WE, COR IW TSE, SAG IW TSE FS) in at least one leg
  - Minimum biospecimen sample, or at least a second try to obtain one’

* Accepted = either of acceptable quality based on central QA review or an image that was not selected for central QA and was accepted by default without QA review. For details of imaging and biospecimen requirements see the Study Design Protocol Appendix H. Minimum Baseline Data Requirements at http://www.oai.ucsf.edu/datarelease/About.asp. The requirements listed in this document were used for the 12-month visit when selecting Image Group B.
No knee replacements
- Based on the clinic’s baseline knee radiograph reading, DID NOT have the combination of one knee with end-stage OA (P01LXRKO2A=6 or P01RXRKO2A=6) and the other knee normal or nearly normal (P01LXRKO2A in (0,1,2) or P01LXRKO2A in (0,1,2)

- had the following at 12-months:
  - Had completed a 12-month follow-up clinic visit as of 5/30/06
  - Accepted* 12-month follow-up visit fixed-flexion knee radiograph
  - Accepted* 12-month 3 key follow-up visit MRI sequences in at least one leg

From this pool of eligible participants, a stratified random sample of 160 was selected, as balanced by clinical center and gender as possible. Due to a lag in recruitment, one of the clinical centers was substantially under-represented in this sample despite selecting all participants from the center who were in the eligible pool, so it was necessary to find additional participants from this center who met the above criteria. Eleven additional eligible participants became available from the most under-represented site by having their baseline images processed after the 1,383 images were transferred to the Coordinating Center, and most of these (those with the most useable images) were substituted for participants with less optimal images from clinic/gender strata that were over-represented in the original sample of 160. The final sample is still slightly unbalanced with not all cells containing 20 participants; under-filled cells were balanced by over-filled cells from other clinics, as much as possible preserving the 50:50 sex ratio of the sample. The final gender balance is 81 females to 79 males.

### Project 04 sample: Distribution of Race by Sex

<table>
<thead>
<tr>
<th></th>
<th>White or Caucasian</th>
<th>Non-White</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>66</td>
<td>13</td>
<td>79</td>
</tr>
<tr>
<td>Female</td>
<td>66</td>
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<td>81</td>
</tr>
<tr>
<td>Total</td>
<td>132</td>
<td>28</td>
<td>160</td>
</tr>
</tbody>
</table>

### Project 04 sample: Distribution of Age by Sex

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>45 to 49</th>
<th>50 to 59</th>
<th>60 to 69</th>
<th>70 to 79</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>12</td>
<td>20</td>
<td>23</td>
<td>24</td>
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<tr>
<td>Female</td>
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<tr>
<td>Total</td>
<td>26</td>
<td>49</td>
<td>43</td>
<td>42</td>
<td>160</td>
</tr>
</tbody>
</table>

Two participants in Image Group B (9239017 and 9905863) had images which could not be analyzed, leaving a total of 158 participants with measurements for Project 04. The original publication of these results listed above presented data for only 156 participants, but since then data from 2 additional participants became available (9192885 and 9755935).

*Accepted = either of acceptable quality based on central QA review or an image that was not selected for central QA and was accepted by default without QA review. For details of imaging and biospecimen requirements see the Study Design Protocol Appendix H. Minimum Baseline Data Requirements at http://www.oai.ucsf.edu/datarelease/About.asp. The requirements listed in this document were used for the 12-month visit when selecting Image Group B.
3. Methods specific to Project 07

3.1 Image type:
Coronal MRI (FLASH water excitation sequence) usually of the right knee, but for the left knee of one participant (1.5mm slice thickness, 0.31mm in-plane pixel size). See the “MRI Manual” link in the operation manuals section of OAI Online at http://www.oai.ucsf.edu/datarelease/OperationsManuals.asp for the acquisition protocol.

3.2 Time points:
Baseline and 24-month visits.

3.3 Measurement methods:
The images were assessed grouped and blinded to chronological order. The technique used is the same as for Projects 04, 08 and 9A.

For Project 07, the femoral regions (cMF and cLF) were defined using 60% of the distance between the trochlear notch and the posterior of the femoral condyle (see Figure 2 above).

3.4 Variables:
Same as Project 04.

3.5 Sample:
The 132 participants included in this project are from Image Group C (first one-half of the combined Progression and Incidence subcohorts) and had FLASH WE images available from baseline, 12-month and 24-month visits that were included in OAI Image Releases 0.C.1, 1.C.1, and 3.C.1.

This project was co-sponsored by the OAI and a private sponsor. The goal was to obtain pilot data on rates of cartilage loss between baseline and 24 months in OAI knees with radiographic OA at baseline. In the related project, Merck Serono funded analysis of baseline and 12-month coronal FLASH WE MRIs of 162 knees (nearly all right knees)¹. Project 07 knees are a subset of 132 from these 162 that had:

- a K&L grade of 2 or 3 based on a musculoskeletal radiologist’s reading that was obtained by the private sponsor; and
- coronal FLASH WE images available (in the same knee) at both baseline and 24-month visits.

For project 07 the OAI funded the analysis of the 24-month MRIs and by agreement with the private sponsor is providing the data from both the baseline and 24-month time points.

¹ These 162 knees consisted of 1) 58 right knees from participants with high BMI and, at baseline, bilateral frequent knee symptoms with advanced radiographic OA in one and less advanced (early) radiographic OA in the other knee (see Project 08 for additional details), and 2) 104 right knees with a K&L grade of 2 or 3 and no other inclusion or exclusion criteria, selected for eligibility assessment based on ascending OAI release ID number. The radiographic criteria were based on a musculoskeletal radiologist’s reading for the cosponsor and not the OAI screening reading.
### Project 07 sample: Distribution of Race by Sex

<table>
<thead>
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<th>White or Caucasian</th>
<th>Non-White</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
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<td>29</td>
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<tr>
<td>Female</td>
<td>77</td>
<td>21</td>
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<tr>
<td>Total</td>
<td>106</td>
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</table>

### Project 07 sample: Distribution of Age by Sex

<table>
<thead>
<tr>
<th>Age (years)</th>
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<th>50 to 59</th>
<th>60 to 69</th>
<th>70 to 79</th>
<th>Total</th>
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<td>10</td>
<td>22</td>
<td>45</td>
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<td>132</td>
</tr>
</tbody>
</table>
4. Methods specific to Project 08

4.1 Image type:
Coronal multi-planar reformat (MPR) images from the Sagittal DESS sequence of right knees. For the MRI acquisition protocol, see the “MRI Manual” link in the operation manuals section of OAI Online at http://www.oai.ucsf.edu/datarelease/OperationsManuals.asp.

4.2 Time points:
Baseline, 12-month and 24-month visits.

4.3 Measurement methods:
The images were assessed grouped and blinded to chronological order. The technique used is the same as for Projects 04, 07 and 9A.

For Project 08, the femoral regions (cMF and cLF) were defined using 60% of the distance between the trochlear notch and the posterior of the femoral condyle (see Figure 2 above).

4.4 Variables:
Same as Project 04.

4.5 Sample:
The 80 participants included in this project are from Image Group C (first one-half of the combined Progression and Incidence subcohorts) and had coronal MPR images in the right knee available at baseline, 12-month and 24-month visits that were included in OAI Image Releases 0.C.1, 1.C.1, and 3.C.1.

The aims of this project were:
1) to compare estimates of cartilage loss obtained from different MRI sequences by obtaining 12-month longitudinal data on cartilage loss using coronal MPR images from a sample of knees that also had longitudinal data on cartilage loss from coronal FLASH WE images and from sagittal DESS WE images
2) to obtain estimates of cartilage loss over 12-months and 24-months from analysis of coronal MPR images.

The OAI funded the analysis of the coronal MPR images and other sponsors funded the analysis of the FLASH WE and sagittal DESS WE images. Only the data from the coronal MPR images are being released for public use. The results of the comparative analyses will be published.

The 80 participants providing data for this project were selected by a private sponsor for a comparison of cartilage loss between the two knees of OA participants who met the following criteria:

• BMI > 25 (mean 31.1 ± SD of 4.0)
• bilateral frequent knee symptoms at baseline (3 participants had pain, but not frequent, in one of their knees)
• advanced radiographic OA in one and less advanced (early) radiographic OA in the other knee at baseline, defined as medial JSN (OARSI grade 1-3) in one knee, but no or less medial JSN in the contra-lateral knee

Participants were selected for eligibility assessment based on ascending OAI release ID number. The radiographic criteria were based on a musculoskeletal radiologist’s reading for the private sponsor and not the OAI baseline screening reading.

NOTE: 58 of these 80 right knees are the same knees that also have coronal FLASH WE images analyzed in Project 07.
### Project 08 sample: Distribution of Race by Sex

<table>
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<th>White or Caucasian</th>
<th>Non-White</th>
<th>Total</th>
</tr>
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<tbody>
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<tr>
<td>Total</td>
<td>59</td>
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### Project 08 sample: Distribution of Age by Sex

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<th>45 to 49</th>
<th>50 to 59</th>
<th>60 to 69</th>
<th>70 to 79</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>5</td>
<td>11</td>
<td>6</td>
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<tr>
<td>Total</td>
<td>10</td>
<td>28</td>
<td>24</td>
<td>18</td>
<td>80</td>
</tr>
</tbody>
</table>
5. Methods specific to Project 9A and 9B

5.1 Image type:
Sagittal DESS sequence of either right or left knee (one per participant selected). For the details of the MRI acquisition protocol used, see the “MRI Manual” link in the operation manuals section of OAI Online at http://www.oai.ucsf.edu/datarelease/OperationsManuals.asp.

5.2 Time points:
Baseline and 24-month visits; 12-month visit if acquired, and for some knees, 48-month, if available at the time of measurement.

5.3 Measurement methods:
The images were assessed grouped and blinded to chronological order. The technique used is the same as for Projects 04 and 07, but projects 9A and 9B differ in their definition of the anatomical region of the femur that was analyzed. Please note that the measurements of tibial cartilage morphology in Project 9B are duplicates of those from Project 9A.

For Project 9A, the femoral regions (cMF and cLF) were defined using 60% of the distance between the trochlear notch and the posterior of the femoral condyle (see Figure 2 above).

For Project 9B, the femoral regions (cMF and cLF) were defined using 75% of the distance between the trochlear notch and the posterior of the femoral condyle (see Figure 2 above).

The regions used for project 9A are the closest to those used when coronal images have been analyzed (projects 04, 07 and 08). Project 9B was performed to examine whether analyzing the femur more posteriorly provided more sensitive measures of progression.

5.4 Variables:
Same as Project 04.

5.5 Sample:
There have been some minor modifications to the data for Projects 09A and 09B. Over the course of those projects, there were some updates to the software which processed the outlines of the articular cartilage and converted them into measurements of volume, thickness and area. Since the previous release of the kMRI_QCart_EcksteinXX datasets (on 5/9/2011, versions 0.4, 1.4, 3.4, 6.3) all of the outlines of articular cartilage have been reprocessed using the latest version of the software, to ensure that data for all knees at all time points were handled in the same way. The changes to the previously released data are insignificant, and were no larger than +0.06mm for cartilage thickness of the main cartilage plates (which typically have mean thickness around 1.5 to 2.0mm), and +42mm³ for cartilage volume of the main cartilage plates (which typically have volumes of 1000-2000 mm³). The changes have affected only the baseline, 12-month and 24-month visit measurements for the first 107 participants analyzed for Project 09A/B.

Subjects for Projects 9A/9B were in the Progression subcohort and were selected for the Core Image Assessment sample. By virtue of being in the Progression subcohort, at baseline these participants had symptomatic OA in at least one knee, defined as the combination of definite osteophytes (OARSI atlas grade 1-3, based on the OAI clinical center screening reading) and in the same knee, frequent knee symptoms. The Core Image Assessment sample was designed to provide longitudinal structural outcomes based on central image assessments. It is composed of Progression subcohort participants for whom 1) a fixed-flexion knee radiograph was available from both the baseline and 24-month clinic visits and 2) a complete set of MRIs was available in at least one knee from both the baseline and 24-month visits. A complete set of MRIs was defined as requiring all of the following: COR IW TSE, SAG IW TSE FS, SAG 3D DESS WE, AXIAL MPR, COR MPR acquisitions.
For inclusion in Project 9A/9B, “Index” knees were selected from among subjects in the Core Image Assessment sample. Index knees were defined as those with 1) frequent knee symptoms, 2) the equivalent of K&L grades 2 or 3 radiographic OA at baseline, using the central adjudicated reading of Project 06 (dataset kXR_SQ_BU00) whenever this was available or else the clinic screening reading was used. When a participant had two “Index” knees, only one knee was selected for Project 09.

Project 9A/9B is now complete and contains measurements for 600 Index knees. There should be no overlap among participants with knees in the Project 04, 07, 08 and 9A/9B samples.

Project 9B differs from Project 9A only in the definition of the femoral region analyzed. The definition used for 9A is similar to that used in Projects 04, 07, and 08.

### Project 09 sample: Distribution of Race by Sex

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<th>White or Caucasian</th>
<th>Non-White</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>206</td>
<td>43</td>
<td>249</td>
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<tr>
<td>Female</td>
<td>220</td>
<td>121</td>
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<tr>
<td>Total</td>
<td>426</td>
<td>164</td>
<td>590</td>
</tr>
</tbody>
</table>

### Project 09 sample: Distribution of Age by Sex

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>45 to 49</th>
<th>50 to 59</th>
<th>60 to 69</th>
<th>70 to 79</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>32</td>
<td>94</td>
<td>62</td>
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<td>249</td>
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<tr>
<td>Female</td>
<td>28</td>
<td>110</td>
<td>135</td>
<td>68</td>
<td>341</td>
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<tr>
<td>Total</td>
<td>60</td>
<td>204</td>
<td>197</td>
<td>129</td>
<td>590</td>
</tr>
</tbody>
</table>
6. Methods specific to Project 18

6.1 Image type:
Coronal MRI (FLASH water excitation sequence) of the right knee (1.5mm slice thickness, 0.31mm in-plane pixel size). For the MRI acquisition protocol, see the “MRI Manual” link in the operation manuals section of OAI Online at http://www.oai.ucsf.edu/datarelease/OperationsManuals.asp.

6.2 Time points:
Baseline.

6.3 Measurement methods:
The images were assessed paired and blinded to chronological order. The technique used is the same as for Projects 04, 07, 08, and 9B. Details are published: http://ard.bmj.com/cgi/content/abstract/ard.2008.089904v2

For Project 18, the femoral regions (cMF and cLF) were defined using 60% of the distance between the trochlear notch and the posterior of the femoral condyle (see Figure 2 above).

6.4 Variables:
Same as Project 04.

6.5 Sample:
This project contains only data from the baseline (V00) visit only, and represents a collection of measurements collected from various projects undertaken by a consortium comprising Chondrometrics, OAI and various pharma partners.

In general these knees are right knee, since that is usually the knee in which the coronal FLASH sequence is acquired. There is 100% overlap between the data in this project and the baseline visit of Projects 04 and 07, but this project (#18) is purely cross-sectional, and cannot be used for longitudinal analyses. The remainder of the sample in this project comprise knees selected using a variety of selection criteria, and were originally longitudinal analyzes. These selections generally involved use of “quasi” Kellgren and Lawrence grades 2-3 (variable P01OARGRDR in the OAI Clinical datasets), although the sample does include some of the non-exposed control cohort, and also some knees with a screening visit clinic reading with a “quasi” Kellgren and Lawrence (variable P01OAGRGR) grade of 4.

These various samples, originally selected for a variety of longitudinal studies, are now combined into Project 18 and have only their baseline visit measurements released.

<table>
<thead>
<tr>
<th>Project 18 sample: Distribution of Race by Sex</th>
<th>White or Caucasian</th>
<th>Non-White</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
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<td>325</td>
<td>38</td>
<td>363</td>
</tr>
<tr>
<td>Female</td>
<td>451</td>
<td>92</td>
<td>543</td>
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<tr>
<td>Total</td>
<td>776</td>
<td>130</td>
<td>906</td>
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<table>
<thead>
<tr>
<th>Project 18 sample: Distribution of Age by Sex</th>
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<th>Total</th>
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<tbody>
<tr>
<td></td>
<td>45 to 49</td>
<td>50 to 59</td>
<td>60 to 69</td>
<td>70 to 79</td>
</tr>
<tr>
<td>Male</td>
<td>47</td>
<td>128</td>
<td>91</td>
<td>97</td>
</tr>
<tr>
<td>Female</td>
<td>69</td>
<td>166</td>
<td>174</td>
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<tr>
<td>Total</td>
<td>116</td>
<td>294</td>
<td>265</td>
<td>231</td>
</tr>
</tbody>
</table>
7. Methods specific to Project 22

7.1 Image type:
Knee MRI scans acquired using a 3D Sagittal DESS sequence. See the “MRI Manual” link in the operation manuals section of OAI Online at http://www.oai.ucsf.edu/datarelease/OperationsManuals.asp for the acquisition protocol.

7.2 Time points:
Baseline, 12-month, and 24-month visit (and 48-month visit in a subset).

7.3 Measurement methods:
The images were assessed paired and blinded to chronological order and OAI ReleaseID. The technique used is the same as for earlier Project numbers.

For Project 22, the femoral regions (cMF and cLF) were defined using 75% of the distance between the troclear notch and the posterior of the femoral condyle (see Figure 2 above).

7.4 Variables:
Same as Project 04.

7.5 Sample:
The knees studied for this project are from the OA Biomarkers Consortium FNIH Project. Further information and details of other data available for this project are provided on a dedicated webpage on OAI Online (https://www.oai.ucsf.edu/datarelease/FNIH.asp) from where specific datasets for just these 600 participants can be downloaded. The data for these knees in these datasets (kMRI_QCart_EcksteinXX for Project 22) are duplicates of the data in the kMRI_FNIH_QCart_ChondrometricsXX datasets.

More information and the analysis of the results from this project can be found in this publication5:

The following table gives some demographic information about the participants with data currently released for the Project 22 data:

<table>
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<tr>
<th>Project 22 sample: Distribution of Race by Sex</th>
<th>White or Caucasian</th>
<th>Non-White</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Male</td>
<td>210</td>
<td>37</td>
<td>247</td>
</tr>
<tr>
<td>Female</td>
<td>265</td>
<td>88</td>
<td>353</td>
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<tr>
<td>Total</td>
<td>475</td>
<td>125</td>
<td>600</td>
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</table>

The following table gives some demographic information about the participants with data currently released for the Project 22 data:

<table>
<thead>
<tr>
<th>Project 22 sample: Distribution of Age by Sex</th>
<th>Age (years)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
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<td>45 to 49</td>
<td>50 to 59</td>
</tr>
<tr>
<td>Male</td>
<td>25</td>
<td>92</td>
</tr>
<tr>
<td>Female</td>
<td>28</td>
<td>120</td>
</tr>
<tr>
<td>Total</td>
<td>53</td>
<td>212</td>
</tr>
</tbody>
</table>
8. Methods specific to Project 66

8.1 Image type:
Knee MRI scans acquired using a 3D Sagittal DESS sequence. For the details of the MRI acquisition protocol used, see the “MRI Manual” link in the operation manuals section of OAI Online at http://www.oai.ucsf.edu/datarelease/OperationsManuals.asp.

8.2 Time point:
Baseline, 12-month, 24-month, 36-month, and 48-month visits.

8.3 Measurement methods:
Publically released OAI images were selected and sent to Chondrometrics for analysis by the POMA Study (Pivotal Osteoarthritis Initiative Magnetic Resonance Imaging Analyses Study https://www.niams.nih.gov/funding/Funded_Research/Osteoarthritis_Initiative/pivotal_mri.asp) with the reading center blinded to case/control selection for that study. For more information about this project, please see the documentation for the kMRI_POMA_TKR_Chondrometrics dataset, and this publication⁶:


For Project 66, the femoral regions (cMF and cLF) were defined using 75% of the distance between the trochlear notch and the posterior of the femoral condyle (see Figure 2 above).

8.4 Variables:
The following parameters are measured in the main cartilage plates (section 1.4b) and subregions (section 1.4c):

- cartilage volume (VC) by numerical voxel integration
- total area of subchondral bone (tAB)
- area of cartilage surface (AC)
- area of subchondral bone covered by cartilage (cAB)
- % area of subchondral bone denuded of cartilage (dAB%)
- normalized cartilage volume (VCTAB) which is AC/tAB
- cartilage thickness over the tAB area (ThCTAB)
- cartilage thickness over the cAB area (ThCcAB)

See section 1.4d for more information about these parameters.

A complete listing of the variables in these datasets can be found in the documentation provided with the dataset, including SAS variable names, descriptive variable labels and attributes.

8.5 Sample:
The knees studied for this project are those selected as part of the POMA Study (Pivotal Osteoarthritis Initiative Magnetic Resonance Imaging Analyses Study https://www.niams.nih.gov/funding/Funded_Research/Osteoarthritis_Initiative/pivotal_mri.asp). This project contains quantitative Magnetic Resonance Imaging (qMRI) measurements as part of a nested, 1-1 matched case/control analysis on the progression of OA leading to knee replacement (KR). Further information about that cohort, including case/control definitions and selection criteria can be found in the documentation for the kMRI_POMA_TKR_Chondrometrics dataset, and this publication⁶:

<table>
<thead>
<tr>
<th></th>
<th>White or Caucasian</th>
<th>Non-White</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>211</td>
<td>24</td>
<td>235</td>
</tr>
<tr>
<td>Female</td>
<td>258</td>
<td>79</td>
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<td>469</td>
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<td>572*</td>
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</table>

*Race data missing for 1 participant

<table>
<thead>
<tr>
<th>Age (years)</th>
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<th>50 to 59</th>
<th>60 to 69</th>
<th>70 to 79</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Male</td>
<td>14</td>
<td>59</td>
<td>75</td>
<td>88</td>
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<td>Female</td>
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<tr>
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<td>201</td>
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<td>573</td>
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9. References


