MULTICENTER OSTEOARTHRITIS STUDY

READING CENTER DATASET DESCRIPTION
QUANTITATIVE MEASUREMENTS OF CARTILAGE MORPHOLOGY FROM MOST 1.5T MRI SCANS

V02MRI15T_LAXITY

MAY 2022

1. Overview

1.1 Contents of dataset

This dataset (*V02MRI15T_Laxity.sas7bdat*) contains centrally performed measurements of cartilage volume, thickness and other quantitative measurements from serial knee MRI scans performed by Felix Eckstein's group at Paracelsus University, Salzburg, Austria. The data contained in this dataset have been used to analyze the use of quantitative cartilage loss as an outcome in MOST (1) and the imaging and data collection were performed as part of R01HD043500 (PI Leena Sharma "Laxity and Malalignment in a Large Cohort Study of OA")

The dataset contains the reading data for two time points – the baseline visit and 30-month follow-up visit. Variables prefixed with V0 are from baseline and V2 are from 30-month follow-up visit. Section 2 of this document describes additional details about the naming conventions used for the variables. The images were acquired using coronal 3D FLASH protocols as outlined in the MOST 1.5T MR Imaging Operations Manual (available online in the "Cycle 1 (BL-15m-30m) MOST Operations Manuals" PDF at https://agingresearchbiobank.nia.nih.gov/studies/most/documents/?f=Manual_of_Procedures).

1.2 Condition

- Dataset strengths/weaknesses:
  - only data from participants with readable baseline and follow-up 1.5T MRI are included in this dataset.
  - the dataset contains one row per knee, and only one knee per participant was analyzed.
  - care needs to be taken when merging with other datasets which might be one row per participant, or one row per knee.
  - calculation of longitudinal changes can utilize the fact that the root of the variable name is the same for equivalent measurements from the two time points

1.3 Variables and reading methods

See the dataset documentation file *VariableGuide_V02MRI15T_laxity.pdf* for a complete list of all the variables in the dataset, their SAS variable names, descriptive variable labels and attributes. Descriptive statistics are given in *Distributions_V02MRI15T_laxity.pdf.* Section 2 of this document provides more details about the variables and their definitions.

2. Technique for segmenting articular cartilage from the MR images

Measurements of volume, 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 for generating the data in these datasets:

- *Eckstein F, et al. One year change of knee cartilage morphology in the first release of participants from the Osteoarthritis Initiative Progression Subcohort - association with sex, Body Mass Index, symptoms, and radiographic OA status. Ann Rheum Dis. 2008 Jul 7. [Epub ahead of print] PMID: 18519425PMID: 18789729* http://ard.bmj.com/cgi/content/abstract/ard.2008.089904v2 (2)
- *Wirth W, et al. Regional analysis of femorotibial cartilage loss in a subsample from the Osteoarthritis Initiative progression subcohort. Osteoarthritis Cartilage. 2008 Sep 11. [Epub ahead of print] PMID:* http://dx.doi.org/10.1016/j.joca.2008.07.008 (3)

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:

- *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 (4)
- *Wirth W., Eckstein F. A technique for regional analysis of femorotibial cartilage thickness based on quantitative magnetic resonance imaging. IEEE Trans Med Imaging. 2008 Jun;27(6):737-44.* http://dx.doi.org/10.1109/TMI.2007.907323 (5)

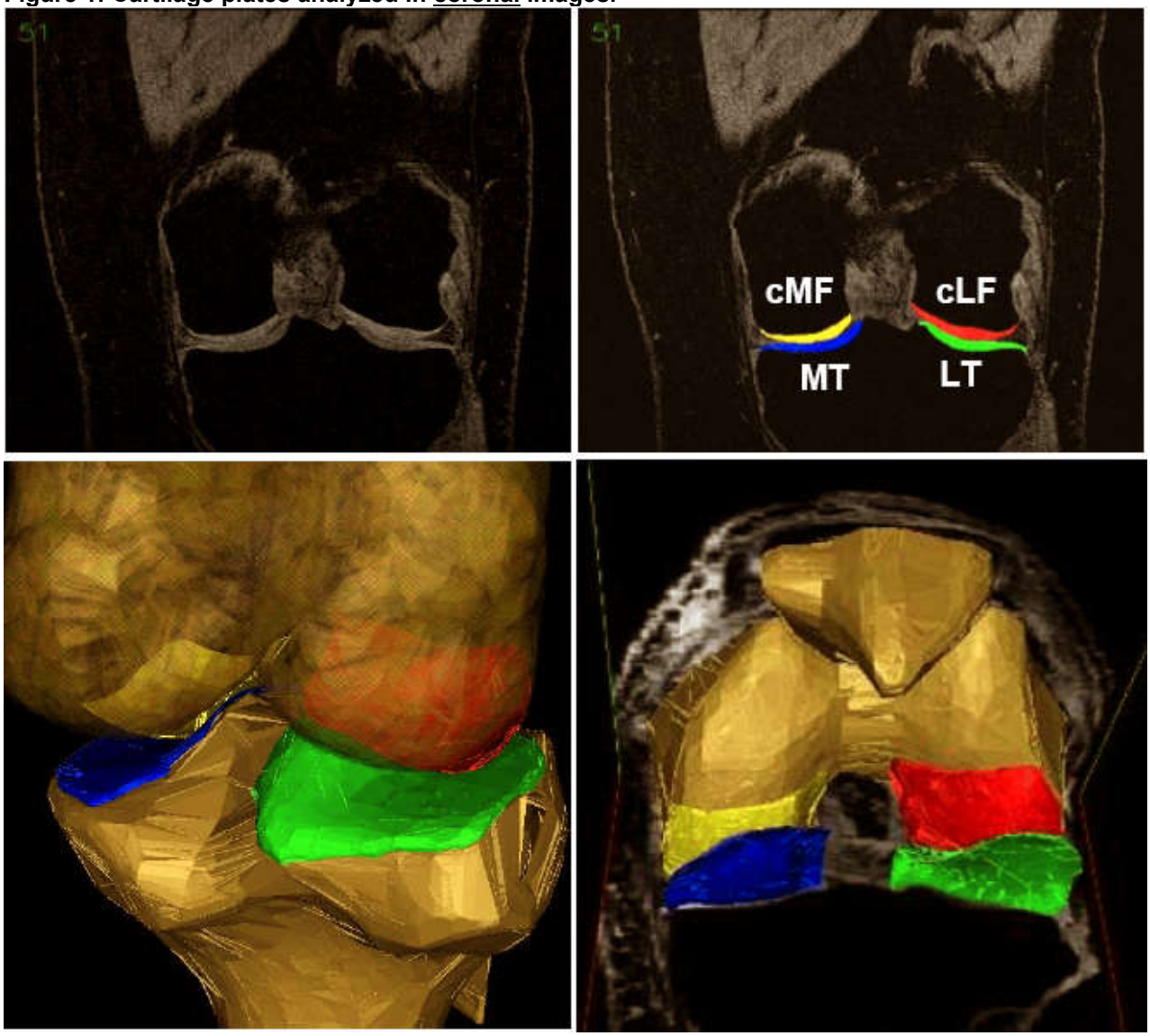
2.1 Main cartilage plates

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

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

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

Figure 1: Cartilage plates analyzed in coronal images.



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.

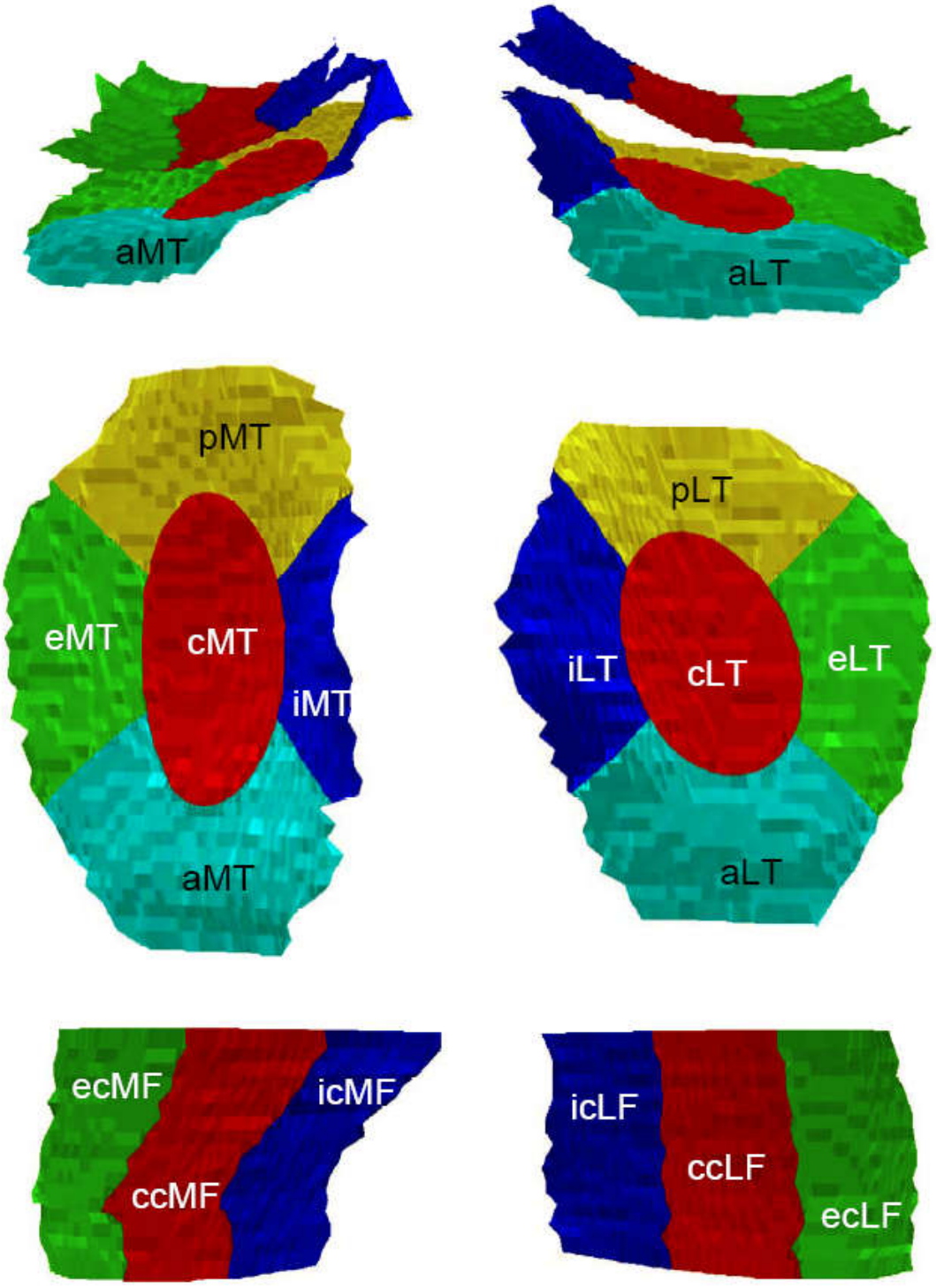
Bottom Row: The images show 3D reconstructions with the bones segmented and the cartilage plates depicted in the same color as in the upper row.

2.2 Subregions of main cartilage plates
This table shows the subregions analyzed in the medial tibio-femoral condyle cartilage plates (also see Figure 2):

Label	Description
cMT	central subregion of medial tibia (20% of tAB) *
eMT	external subregion of medial tibia
iMT	internal subregion of medial tibia
aMT	anterior subregion of medial tibia
pMT	posterior subregion of medial tibia
ccMF	central subregion of central (weight-bearing) medial femur (33% of tAB)
ecMF	external subregion of central (weight-bearing) medial femur (33% of tAB)
icMF	internal subregion of central (weight-bearing) medial femur (33% of tAB)
cMFTC	central medial femoro-tibial compartment +
* 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 2).

Figure 2: 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

2.3 Structural features and metrics

This table shows the measurements of structural features and metrics provided for various cartilage plates and subregions (also see Figure 3).

Label	Unit	Description
VC	(mm^3)	cartilage volume (computed by numerical voxel integration)
tAB	(cm^2)	total area of subchondral bone
AC	(cm^2)	area of cartilage surface
cAB	(cm^2)	area of subchondral bone covered by cartilage
dAB%	(%)	% area of subchondral bone denuded of cartilage
VCtAB	(mm)	cartilage volume divided by tAB (normalized cartilage volume)
ThCtAB	(mm)	cartilage thickness over tAB
ThCcAB	(mm)	cartilage thickness over cAB

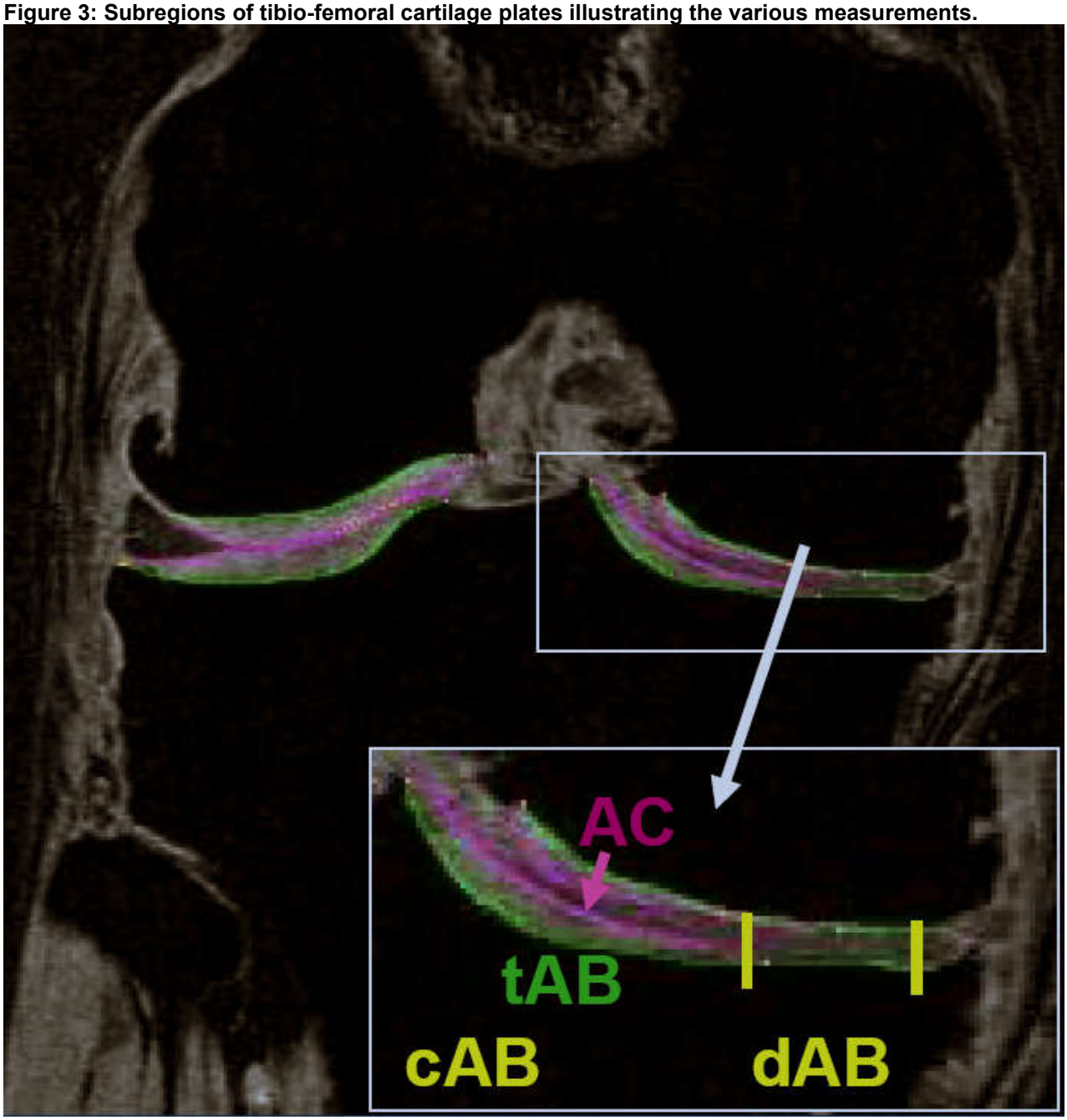
Note: volumes have been computed by numerical voxel integration and not after surface reconstruction in cases where cAB = tAB (no denuded area present), ThCcAB = ThCtAB.

2.4 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.

Label	Description
aMe	**mean cartilage thickness** = the algorithm computes the average of two distances: distance from AC to tAB (c) and from tAB to AC (b), respectively.
aMiv	**minimum cartilage thickness** = 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.
aMav	**maximum cartilage thickness** = 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
SD	**SD of cartilage thickness** = standard deviation of cartilage thicknesses over a given area. This is a measure of the variation in cartilage thickness over a given area.
CV	**CV% of cartilage thickness** = 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.

Figure 3: 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.

2.5 SAS variable names

See the dataset documentation file *VariableGuide_V02MRI15T_laxity.pdf* 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 do not 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. V0 = 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.

Ending of SAS Variable Name	**Structural features and metrics**	
	Label[1]	**Description**
VCL	VC	cartilage volume
SBA	tAB	total area of subchondral bone
ACS	AC	area of cartilage surface
CAAB	cAB	area of subchondral bone covered by cartilage
PD	dAB%	% area of subchondral bone denuded of cartilage
VCN	VCtAB	normalized cartilage volume (cartilage volume divided by tAB)
MTH	ThCtAB.aMe	mean cartilage thickness over tAB
MTC	ThCcAB.aMe	mean cartilage thickness over cAB
MAV	ThCtAB.aMav	maximum cartilage thickness over tAB
MAT	ThCtAB.aMiv	minimum cartilage thickness over tAB
CTS	ThCtAB.aSD	standard deviation (SD) of cartilage thickness over tAB
ACV	ThCtAB.aCV	coefficient of variation (CV) of cartilage thickness over tAB

[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 (4)

Notes:

Section 2.4 describes the differences and methods of calculating the different cartilage thickness metrics

Also note that not all structural features exist for each anatomical location.

3. References

1. Guermazi A, Eckstein F, Hayashi D, Roemer FW, Wirth W, Yang T, Niu J, Sharma L, Nevitt MC, Lewis CE, Torner J, Felson DT. Baseline radiographic osteoarthritis and semi-quantitatively assessed meniscal damage and extrusion and cartilage damage on MRI is related to quantitatively defined cartilage thickness loss in knee osteoarthritis: the Multicenter Osteoarthritis Study. Osteoarthritis Cartilage. 2015 Dec;23(12):2191-2198. doi: 10.1016/j.joca.2015.06.017. Epub 2015 Jul 8. PMID: 26162806; PMCID: PMC4957527. https://doi.org/10.1016/j.joca.2015.06.017

2. Eckstein F, Maschek S, Wirth W, Hudelmaier M, Hitzl W, Wyman B, Nevitt M, Hellio Le Graverand MP. One year change of knee cartilage morphology in the first release of participants from the Osteoarthritis Initiative Progression Subcohort - association with sex, Body Mass Index, symptoms, and radiographic OA status. Ann Rheum Dis. 2008; 68(5): 674-679 PMID: 18519425 http://dx.doi.org/10.1136/ard.2008.089904

3. Wirth W, Hellio Le Graverand MP, Wyman BT, Maschek S, Hudelmaier M, Hitzl W, Nevitt M, Eckstein F Regional analysis of femorotibial cartilage loss in a subsample from the Osteoarthritis Initiative progression subcohort. Osteoarthritis Cartilage. 2009; 17(3): 291-297. http://dx.doi.org/10.1016/j.joca.2008.07.008

4. Eckstein F, Ateshian G, Burgkart R, Burstein D, Cicuttini F, Dardzinski B, 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

5. Wirth W., Eckstein F. A technique for regional analysis of femorotibial cartilage thickness based on quantitative magnetic resonance imaging. IEEE Trans Med Imaging. 2008 Jun;27(6):737-44. http://dx.doi.org/10.1109/TMI.2007.907323