Bone microarchitecture analysis:

The missing information in the subchondral bone

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Introduction

Osteoarthritis (OA) is the most common form of arthritis and affects in a disproportional way the knee. The prevalence of OA is about 15% [1, 2] which is roughly 1 out of 7 people. The conventional method for assessing OA focuses mostly on visually detectable changes to the joint gap using conventional radiographs. Recent research developments in imaging options showed that OA is not just a joint disease but also involves progressive changes in the subchondral/subarticular bone area of the tibia [3,4,5,6]. Besides the accepted methods of measuring the joint space width (JSW), assessments of the trabcular bone structure in selected regions of interest (ROI) of the knee based on conventional x-rays may be offering an alternative method for quantifying the risk and progression of the disease. Novel texture algorithms have been developed to address this question and initiate a new chapter in radiological OA diagnostics

BMAx - Software

The BMAx (Bone Micro Architecture) software features three texture algorithms, which each use unique methods to access significant information in radiographs. The measurement region is selected automatically by a standardized mask placement in the tibia and femur.

Texture algorithms

Bone Structure Value (BSV)

The BSV (Bone Structure Value) algorithm analyzes the self-similarity (uniformity in the fractal dimension) of bone structures based on the gray values of an x-ray image and can thus provide a statement about the smoothness of the structure.

Bone Anisotropy Value (BAV)

This algorithm investigates the bone structure for its chaotic properties. The larger the variation of the gray values, the higher the entropy value.

Bone Roughness Value (BRV)

Similar to the BSV, the BRV algorithm uses the fractal dimension to assess the roughness of the trabecular bone structure. Different directions (angles) are used to investigate the bone properties of the underlying pixel structure.

Mask design

The measurement regions or regions of interest (ROIs) are defined by an interactive mask. The position and size of this measurement mask is based on two landmarks which are automatically placed on the outer tibia plateau edges. If necessary the position of those landmarks can be manually altered.

Two ROIs are available:

The 3x8 mask

The layout features a matrix of 3 rows and 8 columns. This enables a detailed analysis resolution for a large area of the tibial subchondral area.

The 4+2 mask

This mask includes also two ROIs in the distal femur condyles. Additional structural information can be assessed, offering a detailed insight into the disease progression of the femur.

Discrimination power

Using the following discrimination methods:

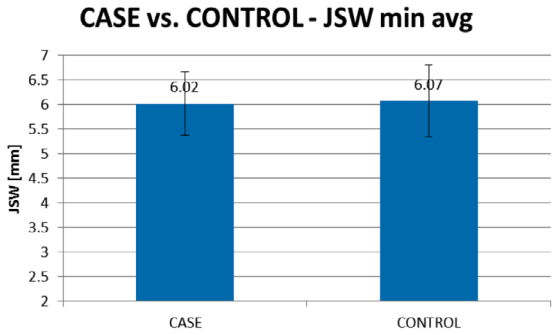
- Feature selection
- Machine learning
- Descriptive correlations

The following results could be achieved for when using texture parameters ONLY:

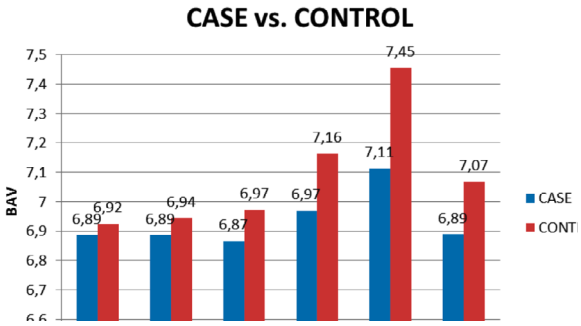
- Area under Curve: 61-86%
- Odds Ratio: 2,75

Potential for early detection

One of the most important aspects of texture algorithms is their potential for early detection. Even if no visible signs of OA are detected, selected areas in the subchondral tibia/distal femur may yield information to early stages of the bone disease. Using the data from the Osteoarthritis Initiative Study (OAI), an analysis was performed using a set of 50 patients without any visible signs of OA at baseline. Half of this population would develop OA at 96 months follow up. Geometrical parameters (JSW) did not show any difference between the two groups at baseline. However, texture algorithms were sensitive enough to detect small variations in the radiographs which were enough to identify parameters for a significant discrimination between patients which may and my not develop OA at a later point in their life.



Texture parameters however could find differences



This clearly shows that the subchondral bone yields information for early detection and that texture algorithms can measure them.

References

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