**A software approach of a new method to diagnose discoid lateral menisci on radiographs**

**authors**

**Abstract**

*Purpose* The aim of this study was to build a software implementation of a previous work, in which a new method to diagnose discoid lateral menisci on radiographs was provided.

*Methods* The method includes measuring shape and length of different parts of the joint on radiograph. Software implementation includes two parts, pre-processing phase and measuring phase. First, machine learning was used to select important parts from the original radiograph image. Basic information of the patient can also be grabbed from the original radiograph in this phase. Then, image enhancement tools were used to strengthen the cut image and remove noises. Edge detection was used to quantify important features in the image. In the second phase, a specific algorithm was designed to build a model of the knee joint, which reflects the internal structure of the knee joint. Once the model has been built, it can help calculate several pre-defined values, which corresponds to different features of the knee joint.

*Results* The software performed well on raw radiographs, showing satisfying success rate and robustness. Output data of the software turned out to be very similar to the result of manual measurement and calculation, which were performed by specialized doctors in previous work.

*Conclusion* It’s possible for the new method to be automated, as tests on its software implementation turned out to have an acceptable result. As a result, it might be possible to diagnose discoid lateral menisci on radiograph with the help of radiograph-image-analyzing software. Also, the results of this study can help build a joint database that contains data from a number of patients, thus can play a role in diagnosis of both discoid lateral menisci and other knee joint diseases in the future.

**Keywords** discoid lateral menisci, radiograph, image processing, machine learning

**Introduction**

Discoid lateral meniscus is an anatomic variant in the knee exhibiting a greater area of the tibial plateau than the normal meniscus. According to previous researches, having a discoid lateral meniscus increases the possibility of meniscal tears, which lead to symptoms such as pain, clicking, swelling, articular block, limitation in knee extension, meniscal instability and formation of meniscal cysts [20]. Discoid lateral meniscus is most found in Asia, and diagnosis of discoid lateral meniscus needs to take both patient’s symptoms and magnetic resonance imaging (MRI) result into consideration. MRI, however, shows several disadvantages in operation. It’s hard to ensure that MRI can be found in every primary hospital, and even in large general hospitals, where MRI is a common tool of diagnosis, patients still have to suffer from the inconvenience of waiting for a long time to make a reservation. Also, MRI has contraindications for patients with magnetic metallic implants or claustrophobia. These all contribute to the need to diagnose discoid lateral meniscus on radiograph, which is far more popular and convenient, as well as having less side-effects.

Due to our previous work [1], a new method to diagnose discoid lateral menisci on radiographs was provided. Sixty patients who were diagnosed with discoid lateral menisci and sixty age- and sex-matched controls with normal medial and lateral menisci were included. A number of geometric distances and angles were measured from the anteroposterior view of plain radiographs, trying to find significant difference between two groups, as shown in Fig.1. As a result, significant difference was found in the values below: HFH (height of the fibular head), LJSD (lateral joint space distance), HLTS (height of the lateral tibial spine), DLC (distance from the lateral tibial spine to the lateral femoral condyle), CDLF (chordal distance of the femoral condyle), HFH/LJSD and LJSD/HLTS.

Fig.1 Geometrical definition of values

In this article, we tried to automate the calculation of LJSD/HLTS by software, as this ratio was found having the most significant difference between patients who were diagnosed with discoid lateral menisci and normal person. Similar researches on radiograph image processing and computer-assisted knee joint analysis had been carried out before: {related works…}

In our work, however, in order to build a software implementation of a method that is based on some trivial shapes of bones in the knee joint, which were reflected as graphic details in the radiograph image, a conservative strategy is preferred, especially during pre-processing phase. When noises are removed from the image, risk also exists that information of trivial parts in the image may lost. Our implementation tried to make sure that no information of edges in the image would be lost, although noises or unneeded edges might still exist in the graph after pre-processing phase. After pre-processing, a well-designed algorithm took over the graph and analyzed it. Higher-level features of knee joint were extracted from the image. These features would not be affected by noises or other kinds of disturbance. This is achieved by analyzing overall distribution of the edges and the orientation of each specific edge.

Then, several pre-defined feature points and lines were drawn in the image, each regarding to an important structural point of the knee joint. These feature points and lines became the geometric foundation of data calculation. Results of the calculation, as proved in previous works, differentiated significantly between normal knee graphs and abnormal ones, thus can help diagnose discoid lateral menisci. These feature points and lines can also be stored as personal information of the patient, as it contains description of femur condyle, tibial plateau and knee joint. Database can thus be built to help record the data of patients’ knee, as well as looking ahead to the possibility of using the data to diagnose other knee diseases.

**Materials and methods**

20 knee X-ray images from normal person and 7 images from patients who were diagnosed with discoid lateral menisci were included in this study. The software accepts a single image as input, without knowing any specific information of the patient. The software will then try to analyze the image and calculate a certain ratio: LJSD/HLTS.

The software includes two parts. The first part is pre-processing phase. In this phase, information will be grabbed from the image. Whether the lateral part of the knee joint is on the left side of the image or on the right side will be decided, the femur axis and tibial axis will also be determined. Next, yolo3 is used to find knee joint in the original image. After knee joint is found and cut off, median filter and histogram equalization will be applied to the image to enhance it and remove noises.

The second part is measurement phase. In the cut image of knee joint, femoral condyle is first found by analyzing the distribution pattern of all edges in the image. The femoral condyle then becomes the base of finding other feature points in the image, including the tibial spine and the tibial plateau. After all feature points are found, several lines are drawn on the image, and calculation is done automatedly by the software. The result of calculation corresponds to several important values mentioned in previous work, which can signify discoid lateral menisci of the patient.

**Pre-processing analysis**

Deciding the orientation of lateral leg in the image

Finding the axis of femur and tibial

Knee joint segmentation, using yolov3

**Image enhancement**

\*Histogram equalization

Histogram equalization is only used when original image has an extremely low contrast. If very few edges are detected, the process will be aborted. Histogram equalization will be used to enhance the image before another try. However, in most cases, histogram equalization will also enhance noises, especially patterns in the radiograph. These patterns are caused by both internal property of human bone and the pants patients are wearing during taking X-ray photo.

Median blur

In our test, simply using median blur in pre-processing phase can reach satisfying result on all of the images. This benefits from our measurement algorithm, which is robust against disturbance and errors in edge detection.

Block-Matching and 3-Dimension filter

BM3D is very effective in removing patterns. (picture) By removing patterns, the result of edge detection is improved. Uncertainty is also reduced in later phases.

(how BM3D worked)

We’ve mentioned above that a loss of detail is not what we want to see in the result of image enhancement. However, BM3D performs well in keeping details in the image. It mainly removes large-scale, regular patterns from the image, which we don’t concern.

**Measurement**

Edge detection

Canny edge detector is used on the cut image of knee joint. Two different group of parameter values are prepared for Canny detector. If one fails, like what we’ve done in histogram equalization, the software will abort and then switch to another group of parameter values and retry. In all of our cases, Canny edge detector can reach a satisfying result which has no negative effect on later operations.

Finding femoral condyle

recognize all horizontal edges

select upper edges

connect upper edges

recognize two femoral condyle feature points, draw the base line of femoral condyle

build coordinate dictionary

\*emphasize: this method successfully found all femoral condyles, thus valuable.

Finding tibial spine

find all tip tops, using distance between femoral condyle feature points as reference.

remove tip top that goes higher than femur edge, or locates at the end of any edge.

\*Our algorithm is unable to deal with situation that tibial spine crosses over femur in the radiograph. However, crossing over of tibial spine and femur can be a signal that possibility of having discoid lateral menisci is very low, and this relieves us from bothering to deal with sophisticated cross-over situation.

Select the two highest tip tops that are far away enough from each other, using distance between femoral condyle feature points as reference.

Find base line of tibial plateau

draw tangents on all edges

remove tangent point that is below femoral condyle base line.

Select two outmost tangent points, one on each side

shift tangent point on its original edge to fix deviation

Calculation

LJSD: distance from up lateral femoral condyle feature point to the base line of tibial plateau

HLTS: distance from lateral tibial spine tip top point to the base line of tibial plateau

The ratio LJSD/HLTS is calculated.

**Results**

7 radiographs of patients who were diagnosed with discoid lateral menisci and 30 radiographs from normal person were included. Mean and standard deviation of LJSD/HLTS were compared with results in previous work, as shown in Table 1.

Table 1

Success rates of each phase are shown in Table 2.

Table 2

**Discussion**

Fail situation analysis.

Disconnected edges, low contrast, pattern on bone, crossing over of different bones

All solved. Special algorithm, histogram equalization/Canny detector retry strategy, BM3D, don’t concern.

Other values can also be calculated based on our algorithm.

HFH can’t be calculated: Locating fiber is a problem unsolved.

**References**