Introduction:

This work evaluates the reproducibility of a new method for measuring the joint space width (JSW) on statically loaded knees from three-dimensional (3-D) MRI data. The system consists of a loading jig (Fig. 1) and JSW analysis software that allows the reconstruction of the two-dimensional (2-D) distance maps between the femur and the tibia bone surfaces.

Fig. 1 Loading device used to apply axial loads during MR imaging

Methods:

- 10 healthy volunteers, (4 males and 6 females; age 26.8±6.1 years; height 168±6.1cm; weight 619±105N) with no history of knee joint injury or pathology, participated in the study after providing consent with approval from our Research Subjects Review Board.

- Two different operators repeatedly positioned each subject in the knee loading device. The loading device imposes an axial load on the target knee that simulates a standing weight approximately equal to half the subject’s body weight. For each positioning, the knee was imaged first in the unloaded, then in the loaded state using a fast gradient recalled echo sequence (TE: 1.9, TR: 7, 1 Nex, Flip angle 40°, time of scan 2:05 min, 64 1.5 mm slices, FOV: 17 cm, 256 x 256 matrix).

- The acquired images were analyzed by an automated 3-D segmentation algorithm that detects spatially independent structures such as the femur and the tibia. Errors presented in the segmentations were corrected by a trained analyst. The resulting segmentations were used by an unsupervised JSW algorithm that identifies the medial and lateral compartments of the knee joint.

- Both unloaded and loaded medial and lateral compartments of the tibia-femur joint space were analyzed by 2-D distance maps, where qualitative and quantitative information was extracted. (Fig. 2)

- The minimum JSW, the overall average, and a localized average within a 5mm radius of the most inferior femur point were evaluated.

- Intra and inter-operator reliability were evaluated by comparing results from repeated image processing and subject repositioning. The intraclass correlation coefficient and standard error of the measurement were calculated for each comparison.

Results:

- Lowest variability in JSW was found in the overall average of the weight bearing region. (Fig. 3, Table 1)

- The location of the minimum thickness changed significantly between the unloaded and loaded sequences for some of the subjects, making it less reliable for analyzing the JSW.

- The localized average thickness proved reliable and less prone to artifact in measurements near the boundaries of the weight bearing regions.

- The intra-operator correlation of the minimum JSW was 0.89, while inter-operator correlation for the same measurement was 0.91. A higher correlation was found between the overall average thickness for both intra and inter-operator, 0.98 and 0.97. (Fig. 3)

Discussion/Conclusions:

- The average JSW decreased more in the medial than the lateral compartment when an axial load was applied, however the decrease was not significantly different from zero.

- The variability in joint space width measurements is mainly associated with the positioning of the subject and not the image processing aspect of the procedure.

- The intra-operator variability is somewhat greater than the inter-operator variability for the average thickness, which suggests that the initial loading helps to settle the knee joint in a steady position. Repeated loading may lead to slight compression that may increase variability.

- As shown previously, a relaxation period prior to image acquisition may be important in reducing variability between measurements.

- Further analysis is required to test the loading device along with the image processing procedures on subjects with osteoarthritic knee joints.

References:


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