INTRODUCTION:

Computerized tomographic (CT) images are commonly used to provide accurate geometrical information of bones; however, magnetic resonance imaging (MRI) is frequently used due to its superior soft-tissue contrast and image acquisition using non-ionizing radiation. In-vivo bony geometrical information is useful for computer simulations of human joints, pre-surgical planning, prosthesis design, and linking joint geometry with associated function and kinematics. Therefore, it is important for the geometrical information extracted from image datasets to be accurate.

Unlike CT, MRI allows the user to select different MR sequences (e.g. fast-spin-echo, gradient echo, etc.) to produce different tissue contrast in the output images. The sequence to be used is determined by how the images will be used, for example: to evaluate a meniscal tear, to visualize a chondral defect or to quantify cartilage volume. It is unclear how different MRI acquisition sequences may affect the accuracy of bony geometry. Therefore, the aim of this study is to investigate the effect of different MR sequences on the accuracy of bony geometrical information of the human knee.

METHODS:

Two fresh frozen cadaveric legs were CT-scanned, using a GE Medical Systems CT-scanner, at 120 kV and 100.00 mAs with a 512 x 512 pixel resolution. The field of view was 30.7 cm, the slice thickness was 0.49mm and the pixel size was 0.6 mm. The MRI data were acquired using 3T scanning systems (GE Healthcare, Waukesha, WI). A 3D spoiled gradient recalled echo (SPGR) sequence (TE: 5.2ms; TR: 17.9ms, acquisition-matrix: 480x480, NEX: 3, field-of-view: 24cm, slice thickness:0.5mm, in-plane resolution: 0.27mm x 0.27mm) was acquired on the first specimen using a quadrature knee coil. Images for the second specimen were acquired using an 8-channel phased array knee coil and a fat-suppressed SPGR sequence (TE: 3ms; TR: 14.6ms, acquisition-matrix: 512x512, NEX: 2, field-of-view: 15cm, slice thickness: 0.6mm) and a 3D XETA [1] sequence (TE:33ms; TR: 2500ms, acquisition-matrix: 512x512, NEX: 0.5, field-of-view: 15cm, slice thickness: 0.6 mm). The in-plane resolution for both series of the series was 0.29mm x 0.29mm.

Three dimensional (3D) models of the distal femur and proximal tibia of each specimen were created from the separate CT and MR datasets using thresholding and region growing techniques. The 3D model from the MRI dataset was registered to the corresponding 3D model from CT-scan data, using both point registration and global registration techniques, employing the least root mean square method (Mimics V13.1, Materialise, Belgium) (Figure 1).

The discrepancies in dimensions of the CT and MRI 3D models of the femur and tibia were calculated at 5 mm intervals, as shown by the red lines in Figure 1, using the Medcad module of Mimics. This method was chosen as opposed to the root mean square of each bone since the magnitude of discrepancy varied with the distance from the joint line. Physical measurements of the bony anatomy were acquired to confirm accuracy of the CT scan data to within 99%. This process was carried out for each of the 3D models to evaluate the different MRI sequences.

RESULTS:

The inaccuracy of the fat suppressed 3D SPGR & XETA sequence was 1.2% at joint line, within 2% from -15 mm to 35 mm, and within 4% from -50 mm to 50 mm. The inaccuracy increased to 9.5% at 80 mm proximally.

The inaccuracy of the 3D SPGR sequence was 4.3% at the joint line, within 4.5% from 0 mm to 45 mm and increased to 7.6% at 80 mm proximally. The discrepancy percentage between the CT and MRI geometries for each cadaver, using the fat suppressed 3D SPGR & XETA and the 3D SPGR sequences are illustrated in Figure 2.

DISCUSSION:

This study evaluated the accuracy of two MRI pulse sequences for quantifying bony geometry around the human knee. Both sets of MRI data gave the least discrepancy at the center of the field of view, corresponding to the joint line. The accuracy of the fat suppressed 3D SPGR & XETA sequence was over three times better than that of the model created from the 3D SPGR sequence near the joint line. The accuracy of the model created from the XETA image data reduced considerably away from the joint line (+50 mm).

The results indicate the importance of selecting the proper MRI sequence for quantifying bony geometry. The XETA sequence with a field of view of 15 cm will give accurate geometrical information, within an accuracy of 2% for evaluating bony geometry near the joint line, such as following a high tibial osteotomy. The SPGR sequence produced inaccuracies of 4.3% at the joint line. This magnitude of error could make the registration of CT and MRI data for applications such as finite element modeling difficult.

Accuracy of reconstructed bone geometries depends on the scanning sequence used. Studies which use 3D models based on 3D MRI datasets may lack the required accuracy if an inappropriate image acquisition sequence is used. It is important to choose the appropriate MRI sequence for the application at hand.

REFERENCES: