Fast dynamic multislice MRI of the human knee using a motion device

D. L. Weber[1,2], S. Klum[2], S. R. Raghuraman[2], J. H. Schrauth[1,2], P. M. Jakob[1,2], and D. Haddad[1,2]
[1]MRB Research Center for Magnetic Resonance Bavaria eV, Würzburg, Bavaria, Germany, [2]Department of Experimental Physics 5 (Biophysics), University of Würzburg, Würzburg, Bavaria, Germany

Introduction

Knee injuries are among the most common injuries of the musculoskeletal system. To date clinical MRI examination of such injuries is mostly performed with static MRI. Unfortunately, static MRI often does not lead to satisfying diagnoses, especially in difficult cases. Dynamic MRI may provide valuable additional information and thus increase specificity and accuracy of the diagnosis in those cases. Possible applications are the diagnosis of ruptures of the cruciate ligaments close to the bone, a characterization of the complex motion of the knee or therapy monitoring after cartilage or ligament reconstruction. To this purpose a motion device was designed and constructed in our lab to enable a reproducible movement of the knee for triggered, segmented, dynamic multislice MRI. In addition, a custom built phased array coil for the human knee was developed in collaboration with the Rapid Biomedical (Rimpar, Germany).

Materials & Methods

The array coil has 16 channels and a knee-adapted U-shape.The prototype of the motion device was designed fully out of MR safe materials (Fig. 1). The patient is placed in a ventral position and the device restricts moving and bending of the leg to a single plane only while keeping the knee at a stationary position. The lower leg can be moved in a well defined manner using a pneumatic cylinder. The bending velocity is adjustable and normally set to 5s per full cycle. The maximum bending angle can be limited to the diameter of the MR scanner and the size of the patient, and in most cases ranges from 25° to 35°. An integrated trigger unit provides information about the current angle and allows synchronizing the motion with the MR experiments. All experiments were performed on a clinical 1.5 T whole body scanner. A segmented FLASH sequence was used to visualize the moving knee (TR/TE = 5.87/2.9ms (opposed phase), slice thickness 5mm, in-plane resolution 0.75×0.75mm², FOV 192×192mm², 21 slices, 4 segments, 14 frames, T_{acq}=7:30 min).

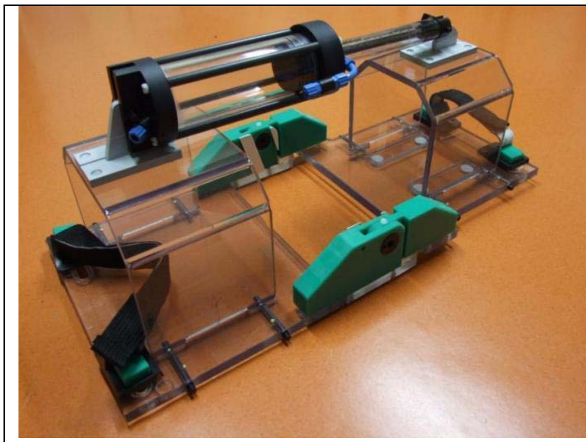

Fig 1: Motion device with pneumatic cylinder.

Results

The reproducibility of the motion was verified using a gel phantom and proved to be more than sufficient: Over 50 cycles the deviation was in the order of 5 %. Since every cycle is triggered individually the error does not accumulate. Thus, a reproducible motion is possible and a segmented multislice dataset can be acquired. Furthermore the reproducibility can be used for averaging over several cycles or to increase the temporal resolution. Using the segmented FLASH sequence with 14 segments, a temporal resolution of 375 ms/frame (2.7 fps) could be realized. Based on the cycle duration of 5s this led to a total acquisition time of 7:30 minutes for all 21 slices. The achieved spatial resolution and the image contrast allows to visualize the different tissues of the moving knee in 3D and over time (see Fig. 2): femur, tibia, patella, infrapatellar fat pad, cruciate ligaments,…

Fig 2: Sagittal images of a moving knee. The knee is shown under different angles, which allows to quantify the movement and deformation of the different tissues (e.g., femur, tibia, patella, infrapatellar fat pad, both cruciate ligaments, …).

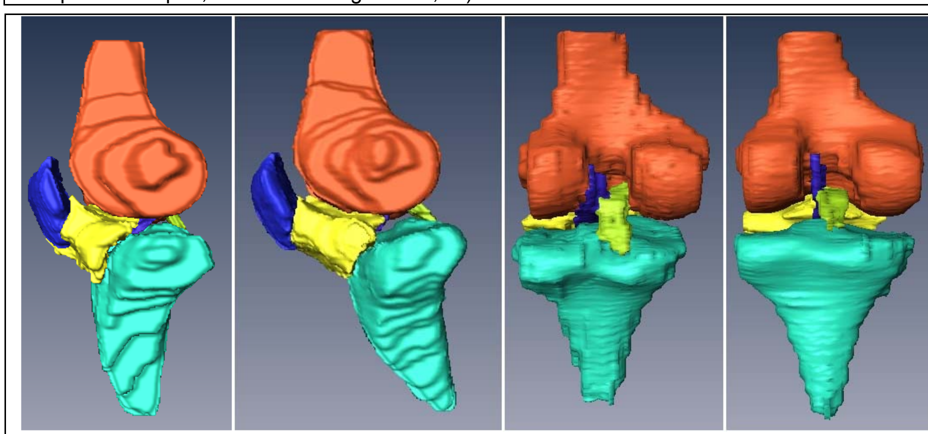

Fig 3: Segmented compartments in the human knee (femur, tibia, patella, infrapatellar fat pad, both cruciate ligaments), shown in two different positions and from two different perspectives. In the left two images one can see the deformation of the infrapatellar fat pad (yellow), in the right images the stretching of the anterior cruciate ligament (blue).

Discussion & Conclusion

With the acquired "dynamic" images a visualization and characterization of the complex movement of the knee is feasible. In contrast to standard static MR images, additional information about the dynamics of the knee is therefore now available and can be shown in MR movies for a better understanding and an easier diagnosis. Based on the very reproducible motion, the temporal resolution of the measurements can be increased to a few milliseconds by using more segments, depending on the specific TR of the applied imaging sequence. Using the sequence parameters described above, a complete measurement of the human knee is possible in less than 8 minutes and can be further accelerated by using parallel imaging techniques. Thus, all the necessary information about the moving knee in various positions is acquired in only a few minutes and is then readily available for medical diagnosis.