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MR microimaging at 7 and 9.4T on small animals joints with ^{1}H for in vivo studies in normal and pathological states and ^{1}H double quanta filter

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Introduction: MRI studies were performed at high field 7T on rats joints in vivo for polyarthritis longitudinal follow-up in time [1]. MRI is technically critical on rats and mice compared with humans. NMR methods were set up and optimized to obtain high resolution sensitive images of the cartilages, which are of interest for studying the normal and pathological behaviors.

Subjects and Methods: Longitudinal studies were carried out at 7T, on a Varian Inova imaging spectrometer equipped with a horizontal 20 cm bore diameter magnet. A diameter surface coil was used. The rat was anesthetized with halothane/O_2/N_2O mixture and its temperature was monitored. NMR parameters were optimized to yield the best images in terms of contrast, sensitivity and resolution, compatible with the timing of potential pharmacological protocols in vivo.

The precocious arthritis damages first the articular cartilage. We are interested to selectively obtain cartilage images. Order in hard biological tissues creates dipolar interactions resulting from anisotropic motion [2,3]. Because the cartilage is composed of oriented collagen fibers, we can use double quanta filtered (DQF) NMR signals of water molecules. ^{1}H DQF experiments were developed at 9.4T, on a varian Inova spectrometer equipped with a vertical 8 cm bore diameter magnet and a microimaging system. A birdcage coil was used. The mouse was anesthetized by hydrate chloral injection.

Results: The T_1 and T_2 relaxation rates of the structures of the articulation were measured.

T_1 and ρ weighting was chosen in the criterium of sensitivity. T_2 weighting gave a good contrast in favor of cartilage but the sensitivity was insufficient for studying the whole joint. Gradient-echo sequences with short TE were

preferred to spin-echo sequences. Comparing with 2D multislices experiments, 3D gradient-echo sequence was more convenient for the global observation of the joint. Lipid suppression by a water peak frequency selective excitation was introduced. To compare the images, we used the crossed ligaments as an anatomical reference mark. The 3D experiments were optimized to run in an hour with a resolution of $0.11 \times 0.11 \times 0.15$ mm^3, a voxel size of $1.7\ 10^{-3}$ mm^3. The final experimental conditions lead to 1 h 20 min total anesthesia time, in order to set up a pharmacological protocol on rats groups. Longitudinal series of normal and pathological rats were studied (mean, four rats/day during 20 days). The cartilages thickness decreased early after induction of polyarthritis. There is also an early erosion of the trabecular bone and the cortical line is destroyed in some regions.

The ^{1}H-^{1}H dipolar interaction in mouse cartilage gives a new contrast parameter for the image and 3D images were recorded at 9.4T in about an hour.

A software has been developed to delineate semi-automatically the boundaries of the joint and to obtain an accurate 3D representation of the surface of the femur head and of the tibia plate. This allows to study the geometry of the joint and its evolution.

Conclusion: The resulting ^{1}H images are of high quality in terms of resolution and contrast. Fine details from the structures of the joint like trabecular bone region as well as cartilages were obtained allowing the study of polyarthritis in rats. DQF imaging also supplied selective data from the cartilage. Future development will consist in computing a map of the thickness of the cartilage. Our results show that the use of micro MRI enables a longitudinal follow-up of rats joints and is a potential powerful method for the study of a treatment of the articular diseases on rats.

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