19F Magnetic Resonance Imaging: Technical Aspects

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Purpose

^{19}F MRI is a growing field with high potential in molecular and cellular imaging; however, overcoming low signal-to-noise (SNR) is a challenge in many applications. Here, we review the current state-of-the-art, focusing on hardware and imaging protocols to optimize SNR per unit time. In particular, we explain the hardware and imaging parameters to make them understandable to biologists and medical researchers working in this field.

Outline

Why ^{19}F MRI?
Signal-to-noise ratio (SNR)
Optimizing SNR per unit time
Quantification of ^{19}F signal
Cell tracking
- Cell ^{19}F loading
- Types of ^{19}F agent
- Reproducibility and longitudinal studies

^{19}F MR hardware
- Coils
- B_1 homogeneity
- Gradient stability

Imaging sequences
- Introduction (brief explanation of key imaging parameters)
- Established imaging sequences
- Experimental imaging sequences
- Sequences in development

Clinical application
- Hardware
- SAR issues
- Sensitivity
- Field strength

Conclusions

Summary

The ^{19}F nucleus occurs at 100% natural abundance. It has a gyromagnetic ratio close to that of ^{1}H, i.e 40.08, and a sensitivity of 83% of ^{1}H. ^{19}F MRI is becoming an important way for spatial mapping of ^{19}F-labeled compounds in molecular/cellular assessment. In particular, ^{19}F MRI is inherently quantitative due to an absence of background *in vivo*. The technique often combines a ^{1}H MRI image co-registered to ^{19}F MR/spectroscopic data which allows visualization of anatomical and pathological information from a single image. In order to acquire images, in a reasonable scan time, sensitivity is a crucial parameter. MR sensitivity increases approximately linearly with magnetic field strength but efficient RF coil design is equally important. Selection of the coil type strongly depends on the application and region of interest to be imaged. For instance, since a surface coil is not spatially uniform and signal falls off with distance from the plain of the coin, it is not a good choice for large areas. In such case, phased array coils may increase tissue coverage and sensitivity. On the other hand, single-frequency mode coils can give rise to inaccurate co-registration of ^{1}H/^{19}F signals due to positional artifacts caused by coil retuning. To overcome this, dual frequency ^{1}H/^{19}F coils have been proposed, where the user tunes and matches both ^{1}H and ^{19}F at the beginning of the session. Scanning protocols and selection of acquisition parameters are also fundamental to good quality images. For instance repetition time (TR) selection, which determines both SNR and acquisition time, is vital. TR is selected according to the T_1 value which could be relatively long for fluorinated molecules and this makes ^{19}F MRI challenging from a scanning time point of view, especially with *in vivo* experiments. In principal, ^{19}F compounds approaching the relaxation ratio $T2^*/T1$ of 1, provide the best sensitivity options. Typically, modified ultrafast and multiple echo imaging sequences are employed to perform the experiments. Finally, we discuss and assess the technology for possible clinical applications in cellular therapeutics, having an eye on safety issues.