Contrast Enhancement for Early Tumor Detection by Active Feedback Self-Nutation

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Introduction

MRI has shown to be useful in a wide variety of applications, but it continues to be elusive in the area of early cancer detection. The difficulty lies in the ability to distinguish between magnetically similar components. And while tumor growth is marked by a high level of angiogenesis, most magnetic properties of early stage tumors remain almost identical to those of their healthy tissue counterparts. We introduce a new imaging technique that makes use of an active feedback field as a mechanism for enhancing contrast by locking the magnetic spin of one component.

Theory and Methods

The magnetic spin evolution under the active feedback field is sensitive to difference in small frequency shifts, and by utilizing this artificially induced field, we can enhance the contrast that conventional imaging lacks [1-3]. Unless the active feedback field is parallel to the direction of the magnetic spin, it induces an oscillation of the magnetic spin back towards the equilibrium position. When the feedback field is parallel to the spin, no rotation occurs, but rather the spin is locked in position until relaxation effects occur. Since the active feedback field can be applied to the sample with particular strength at an indicated phase angle, we can utilize the active feedback field as a tool to engineer the transverse magnetizations. A mechanistic view of the spin dynamics for this method is presented in Figure 1. Initially, the two components, which have a small frequency shift and concentration difference, are aligned along the external magnetic field. A radiofrequency pulse in the y-direction is applied to rotate the spins into the transverse plane and in panel 3, the two spins are allowed to dephase for a short amount of time before the active feedback field is applied parallel to the bulk component. The minor component is rotated back towards equilibrium but the bulk magnetization remains spin locked. The effectiveness of the active feedback self-nutation relies on the difference in concentrations between the components as well as a resonance offset from magnetic susceptibility difference; in early tumor legions, these two factors occur naturally.

Results

Mice with early stage colon cancer were imaged at 7-T using conventional and active feedback self-nutation imaging techniques (Fig.2). While the majority of the conventional methods show no indication of a tumor, our method is successful in highlighting the tumor mass with a close correlation of the size as demonstrated by comparison with histopathology (Fig.2E,G).

Discussion and Conclusion

These results suggest that the active feedback fields can selectively lock spin components with a small frequency shift and concentration difference within an inhomogeneous sample to generate contrast, which would otherwise be difficult to obtain in conventional imaging. From our experiment with early tumor mice, we show that this concept can be applied for early tumor detection.

References

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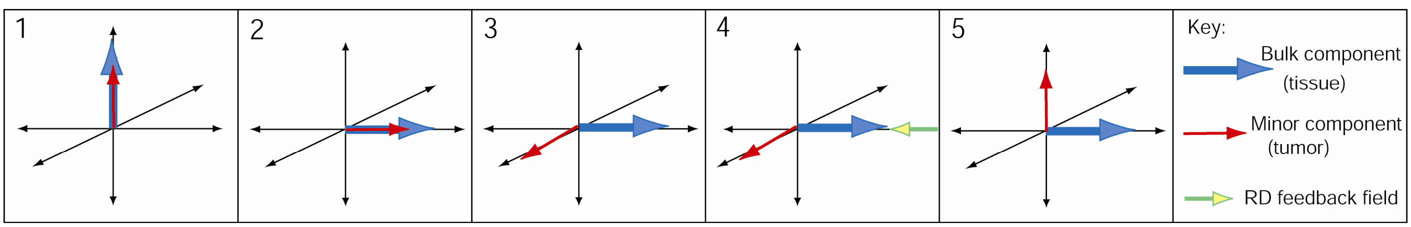

Figure 1: Spin lock mechanism of active feedback self-nutation method.

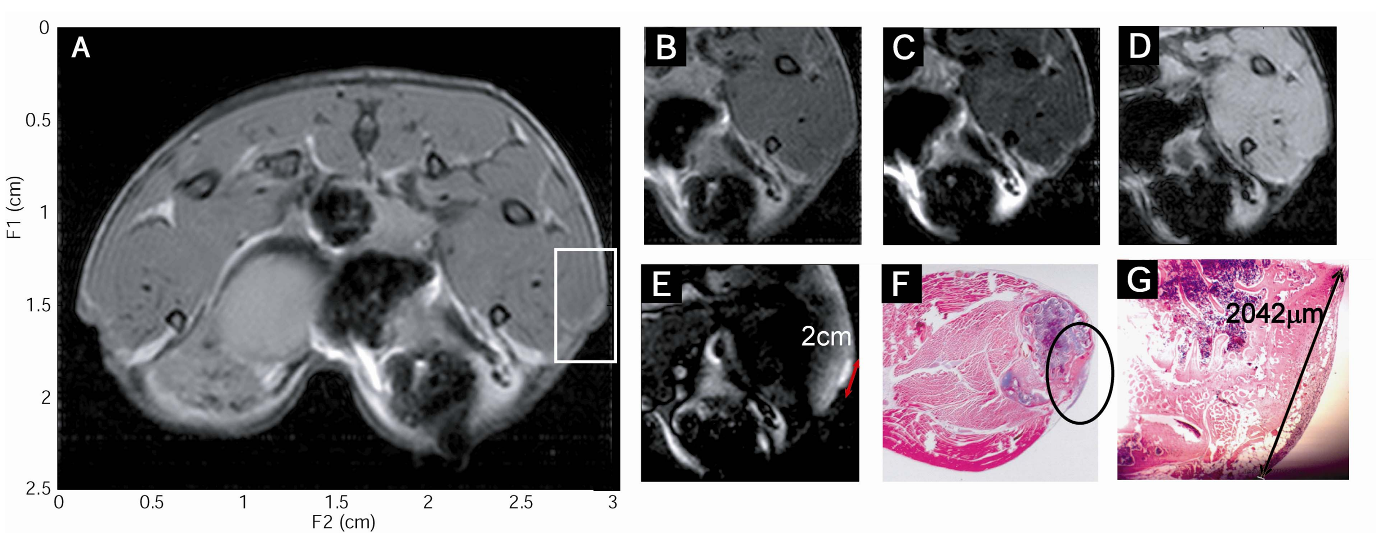

Figure 2: A) Proton density. **B)** T1-weighted image. **C)** T2-weighted image. **D)** T2*-weighted image. **E)** RD Nutation image. **F)** Histopathology with section of interest circled. **G)** Magnified region of interest containing tumor mass.