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大鼠模型在神经退行性疾病、脑血管病及脑损伤等研究中具有重要的应用价值,无创性 MRI 是探索大鼠脑结构与功能的重要工具。然而,临床常用的 3 T MRI 扫描仪用于大鼠神经成像时,存在信噪比(signal-to-noise ratio, SNR)低、图像分辨率不足等局限。尽管 5.0 T 超高场临床 MRI 系统在 SNR 上较 3.0 T 有明显优势,但其人体孔径与大鼠较小体型不匹配,仍制约了成像质量的进一步提升。

近年来,超材料技术通过调控射频近场,可显著增强局部 MRI 信号,且无需改动扫描仪硬件。本研究在 5.0 T 临床 MRI 系统上,以健康雄性 SD 大鼠为对象,首次系统对比了“超材料联合 48 通道头线圈”与“大鼠专用线圈”两种成像方案的图像质量与扫描效率。结果显示,在相同扫描时间和空间分辨率下,超材料方案使 T1WI、T2WI、T1WI-液体衰减反转恢复(fluid attenuated inversion recovery, FLAIR)和 T2WI-FLAIR 序列的 SNR 分别提升了 26%、53%、64% 和 68%(均 $P<0.05$);在匹配至相当 SNR 时,超材料方案使 T2WI、T1WI-FLAIR、T2WI-FLAIR 序列的扫描时间分别缩短 55%、53% 和 61%。

上述结果表明,超材料能够显著提升临床 MRI 系统下大鼠脑部成像的 SNR 与采集效率,有助于缩短动物麻醉时间、降低实验风险,为利用临床设备开展高质量小动物影像研究提供了可推广的低成本高性能方案。详见内文第 133 页。

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About the cover

Rat models have significant application value in the study of neurodegenerative diseases, cerebrovascular disorders, and brain injury. Noninvasive MRI is a crucial tool for exploring the brain structure and function of rats. However, when using clinical 3 T MRI scanners for rat neuroimaging, limitations such as low signal-to-noise ratio (SNR) and insufficient image resolution are commonly encountered. Although the 5.0 T ultrahighfield clinical MRI system offers substantial SNR advantages over 3.0 T, the mismatch between the human size bore and the small body size of rats continues to constrain further improvements in image quality.

In recent years, metamaterial technology has emerged as a promising solution. By modulating the radiofrequency nearfield, metamaterials can markedly enhance local MRI signals without requiring any hardware modifications to the scanner. In this study, using a 5.0 T clinical MRI system and healthy male SpragueDawley rats, we systematically compared the image quality and scanning efficiency of two imaging setups for the first time: a metamaterial combined with a 48-channel head coil versus a dedicated rat coil. Under identical scan time and spatial resolution, the metamaterial setup significantly improved SNR across T1WI, T2WI, T1WI-fluid attenuated inversion recovery (FLAIR), and T2WI-FLAIR sequences by 26%, 53%, 64%, and 68%, respectively (all $P < 0.05$). When the scan parameters were adjusted to achieve equivalent SNR, the metamaterial setup reduced scan time for T2WI, T1WI-FLAIR, and T2WI-FLAIR sequences by 55%, 53%, and 61%, respectively.

These findings demonstrate that metamaterials can substantially enhance both the SNR and acquisition efficiency of rat brain imaging on clinical MRI systems, thereby helping to reduce animal anesthesia time and experimental risks. This approach provides a low-cost, high-performance, and readily generalizable solution for conducting high-quality small-animal imaging studies on clinical scanners. Please see text page 133.