Fatal Imaging and Spectroscopy at Zero Tesla

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Introduction

The determination of the optimum magnetic field strength has a long tradition in the development of MRI (1,2). For example, traditional high-field claims of improved signal-to-noise and resolution are often counterbalanced by a more pronounced sensitivity to artifacts from motion, flow, chemical shift, and susceptibility effects.

Instead of moving to 8 T (3) or beyond and as a follow-up to the genuinely intriguing results of J. Coupling et al (4) as well as D.F. Sobel et al (5), the purpose of this work was to investigate the utility of extremely low fields. In fact, all experiments were performed at zero Tesla including anatomical brain imaging, localized neurospectroscopy, and functional neuroimaging.

Methods and Subjects

All studies were carried out at 0.0 T using a standard Siemens Vision (Erlangen, Germany) during a magnet service time. Approval by the local ethical committee was not obtained in time. A large variety of sequences was tested including T1-weighted 3D FLASH and T2-weighted fast SE for anatomic MRI as well as T2*-weighted FLASH and EPI for functional neuroimaging. Mapping of the visual cortex was based on a robust paradigm (checkerboard vs. gray screen). Localized proton spectra were obtained from an 8 ml VOI in parieto-occipital gray matter using a STEAM sequence (TR/TE/TM = 6000/20/10). Additional tests involved non-proton MRI and MRS. No special equipment was required at zero Tesla.

The study design included three different controls to exclude confounding 'placebo' effects: (i) experiments without any equipment, (ii) experiments in which 6 healthy young subjects (age 21–34 y, mean 26.3 y) were not examined, and (iii) full examinations of no subjects.

Results and Discussion

Anatomic MRI. The most relevant finding was that images at zero Tesla show no artifacts at all. It should be noted, however, that this gain in performance over high-field systems is at the expense of reduced signal-to-noise.

Proton MRS. The acquisition of zero Tesla proton MR spectra is characterized by a tremendous simplification to a single resonance at zero frequency. Unfortunately, the general utility of this single-line spectrum may be hampered by its limited chemical specificity which results from a misbalance between the real and imaginary RF receiver channels.

Non-proton MRI and MRS. A surprising physical observation is the fact that zero Tesla NMR studies are effectively independent of the gyromagnetic ratio. For example, this finding favorably translates into proton and sodium MR images of similar quality and also leads to identical proton and phosphorus spectra.

Moreover, the achievable signal-to-noise ratio does not depend on the measuring time. In fact, it is not even necessary to perform any experiment at all. This unexpected finding was confirmed by three independent strategies: results of similar quality were obtained by either using no equipment or no subjects or by not performing experiments.

Functional neuroimaging. The only pitfall at zero Tesla was a potentially harmful result obtained for functional neuroimaging. Pertinent studies revealed a lack of activation in all subjects even when using a robust visual activation paradigm. These observations rise some serious concern of putatively hazardous effects and require new safety considerations for studies at zero Tesla. When retesting our subjects at higher fields all had recovered without any signs of irreversible cognitive or mental distortions.

Conclusion

In many respects, the present findings confirm previous predictions for MRI and MRS at zero Tesla. Unavoidable losses in signal-to-noise at this low field need to be addressed and are currently under investigation.

On the other hand, zero Tesla drawbacks are more than compensated for by the absence of any MRI and MRS artifacts as well as by substantial savings in the experimenter's and patient's time. Moreover, the strategy allows for a significant reduction of costs of both the actual examination (which does not need to be performed) and the used equipment (which does not need to be purchased).

Obviously, a more widespread use of zero Tesla MRI and MRS will lead to dramatic socioeconomic consequences: health care costs for diagnostic procedures will be cut infinitely, and the necessary adjustments in radiology as well as in the medical industry may become revolutionary.

References

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