Rapid Large Field-of-View Microscopy Using Parallel Imaging

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INTRODUCTION

One of the most intriguing features of MR imaging is the ability to obtain essentially arbitrarily high resolution by the use of stronger gradients. The smaller pixel dimensions, however, result in a severe intrinsic SNR penalty, typically overcome by obtaining many averages and/or the use of small surface coils with higher coil SNR, where the SNR increase is inversely proportional to the square root of the coil diameter (1). At microscopy resolutions, a conventional 256x256 image provides a relatively small field-of-view, insufficient (or at least inconvenient) for many applications. For example, particularly in surface microscopy, it may be of interest to image larger regions of the skin or other tissue, including grafts, vessel walls, and brain sections (2-5). Arrays of microcoils have been investigated and are in use as a means to reduce the scan time of the lengthy microscopy experiment (6), and using large arrays to simultaneously increase coverage is a natural extension facilitated by the increase in receiver availability. In this abstract we demonstrate rapid MR microscopy with a large field-of-view. This is achieved in one dimension (phase encoding) through the use a 64-element array and in the second dimension (frequency encoding) by a 64-channel digital receiver. This system provides improved SNR through the use of small surface coil elements, reduces the number of phase encode steps through the use of parallel imaging with the array, and enables large field-of-view in the frequency direction by using 64 independent fast receivers, each with 1.25 MHz bandwidth.

METHODS

In conventional MR imaging, resolution is determined by the extent of k-space sampled and the field-of-view is determined by the number of samples of k-space obtained within this range. Thus, the combination of high resolution and a large FOV in the phase encode direction requires a large number of phase encoding steps, with image acquisition time proportional to the matrix size. In the frequency encoding direction, the field-of-view can be increased for a given resolution without time expense by obtaining more samples, simply dependent upon the capabilities of the receiver. To test the performance of the parallel large-scale microscopy system, a 64-channel array coil (sixty-four 2mm x 8cm elements) and a 64-channel broadband receiver described elsewhere were used (7), the advantages of which are graphically described in Fig. 1. To illustrate the utility of the system, multiple laboratory samples of human cerebral cortex and cerebellum were placed on the array in lieu of a single large sample. Three sets of images were obtained for comparison – two conventional MR images using a custom designed surface coil and the Omega receiver and one image formed using the 64-channel array and digital receiver. The two conventional MR images differed only by the number of averages taken (one with Nav=1 and one with Nav=8) and the remaining imaging parameters were as follows: FOV 12.8x12.8cm, Np x Nf = 512x1024, TR/TE = 250/40 msec. The nominal resolution was therefore 250x125 microns, with the single-average image acquired in 2.13 minutes and the eight-average image acquired in 17.1 minutes. Next, to test the microscopy array, the Omega was set to obtain a 64x128 image with a 1.6 cm FOV, for the same nominal resolution of 250x125 microns. As before, TR/TE was 250/40 msec., and a single average was used, giving a total imaging time of only 16 seconds. Due to phasing properties of the microcoil array elements (8), only 34 out of 64 of the phase encoding lines were used in reconstruction, resulting in an effective imaging time of 9 seconds. The matrix size in the frequency encode was set to 1024 in the digital demodulation, providing an unaliased FOV of 12.8cm in that direction. By registering and summing an overlapping 3.75mm FOV from each of the parallel 64 coils, where the 2mm wide coils were 8 pixels center-to-center, a phase encode field-of-view of 12.8cm in a 512 point matrix was also obtained.

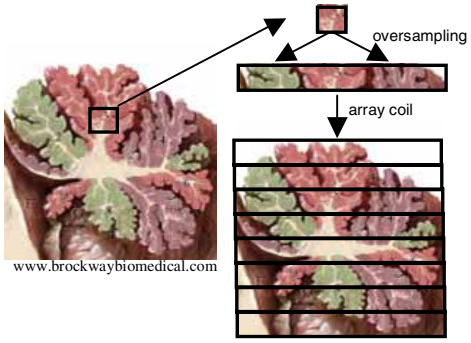
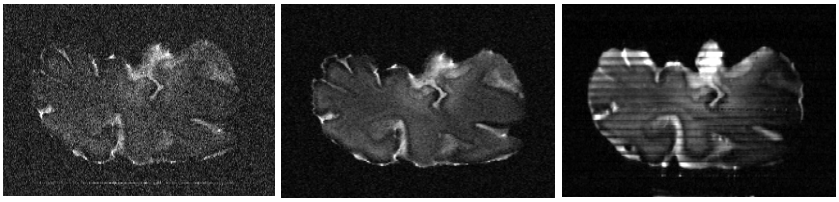


Fig. 1 Depiction of the benefits of an array of broadband receivers and coil elements. The FOV is extended in both directions using the oversampling ability of the digital receiver and the parallel imaging capability of the array.

RESULTS & DISCUSSION

Figure 2 shows corresponding images from the surface coil and array coil as well as image acquisition times and average SNR comparisons. For clarity in visual comparison, only a single sample of cerebral cortex is shown. Despite taking only nine seconds to acquire, the array coil image compares favorably to the eight-average, 17 minute surface coil image with regard to SNR and the definition of structure on the cortical surface. The banding artifacts in the array image are due to the very localized coil patterns and could eventually be corrected in software or with alternative element spacing. Applications of this work appear to be in two distinct directions. Further increasing the resolution while maintaining the FOV is possible through the large matrix sizes supported by this technique, but will entail significant data handling and processing and is a work in progress. For the large but more modest matrix sizes presented here, this technique appears to provide the potential for monitoring more dynamic processes than accessible through the conventional microscopy paradigm.



surface coil	surface coil	array coil
Nav = 1	Nav = 8	Nav = 1
512x1024	512x1024	512x1024
SNR = 13	SNR = 34	SNR = 40
Time: 2 min	Time: 17 min	Time: 9 sec

Fig. 2 Comparison of surface coil images and array coil images

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Support from the NIH (1R21EB003296-01A1) is gratefully acknowledged.