SINGLE-SHOT IMAGING *IN VIVO* AT 4.7 TESLA OF LOCALIZED SELECTED VOLUMES BY STEAM-EPI

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Introduction:

Echo-Planar Imaging (EPI) is theoretically one of the fastest possible magnetic resonance imaging (MRI) methods, allowing the acquisition of the whole time domain data set in only a single scan (*1*). Therefore it has important potential for clinical studies. This method should be particularly appropriate for imaging moving organs. However, it has not yet become a widespread tool in clinical research on commercial machines, mainly because of its stringent hardware requirements. The gradient switching times available for many state-of-the-art instruments today still necessitate acquisition times on the order of 50 ms to 100 ms for 64 x 64 images, which implies that an excellent B_0-homogeneity is prerequisite for EPI imaging. Such homogeneity is generally not to be found on whole body instruments.

One way around the homogeneity difficulty is inner volume imaging. "Zooming" the volume of interest (VOI) is not only a means to obtain high resolution images of restricted areas within the sample (*2, 3*), but also makes such areas accessible to EPI because of the better homogeneity generally found in a small volume. Combining the STEAM-technique (*3, 4*) for localization with EPI (*5*), we have obtained images of selected VOI's in cat brain. The method and the results are presented, and further possible improvements are discussed.

The STEAM-EPI Sequence:

The STEAM sequence consists of three 90° rf-pulses which generate a stimulated echo. When each of these pulses is frequency selective in the presence of mutually orthogonal field gradients, the stimulated echo originates from a VOI which is the intersection of the three selected planes. Some additional strong gradient pulses ("crushers") prevent the detection of any NMR signal other than the stimulated echo, and assure thereby an excellent degree of localization in a single acquisition. In the STEAM-EPI sequence, one of the selective pulses determines the image slice-thickness, and the two others the size of the VOI in the readout and in the phase encode directions. Therefore, the imaging parameters can be chosen in such a manner that the field of view (FOV) is as small as the selected VOI, and the resolution available in the instrument thus is focussed on this area.

About the moment where the stimulated echo occurs, the echo planar image acquisition takes place: a negative gradient lobe first dephases the signal, and then the sampling of the NMR signal starts in the presence of one constant and one oscillating gradient. For the image reconstruction, the data acquired during alternate lobes of the oscillating gradient have to be time reversed before Fourier transformation. We currently use the MBEST ("modulus blipped echo-planar single-pulse technique", (*6*)) variation of EPI in which all of k-space is sampled, and which therefore allows to use real and imaginary data in the frequency domain to yield a modulus image.

Experimental:

Experiments have been conducted on a General Electric CSI 4.7 Tesla instrument equipped with 'Acustar' shielded gradients. An anesthetized cat was placed in the magnet with a surface coil placed on its head ($\emptyset_i$ = 4.5 cm). First the magnet was shimmed on the whole head as observed using the surface coil for transmission and reception with a single-pulse sequence, then the homogeneity was adjusted on a slice parallel to the surface coil plane through the brain of the cat. The resonant frequency of the water line was determined, and both standard spin-warp and EPI images were acquired. From the images, the coordinates of a region of interest were determined. The oscillating gradient for EPI imaging was generated by playing out a table of precalculated values. The images were reconstructed in a few seconds using CSI hardware. Care was taken to ensure that the echoes remained equally spaced after time reversal of alternate echoes, in order to decrease the intensity of the ghost due to asymmetry between odd and even echoes.

Results:

The images shown here were obtained in the brain of an anesthetized cat at 200 MHz. After the shimming procedure, the measured linewidths at half height were 20 Hz on the whole head, and 9.5 Hz on a selected volume within the brain on a horizontal slice. Using the STEAM sequence for slice selection and eventually for volume selection, images were acquired with both the standard spin-warp and the MBEST imaging schemes. The MBEST images were zerofilled before Fourier transformation to yield 128 x 128 pixel images.

Figure 1: A spin-warp image of the cat's brain. The resolution during acquisition was 64 x 128 pixels for a FOV of 80 x 80 mm, yielding a pixel size of 1.25 x 0.63 mm. The slice thickness was slth = 4 mm, the echotime TE = 80 ms. In total, 64 scans (1 per phase encoding step) were acquired.

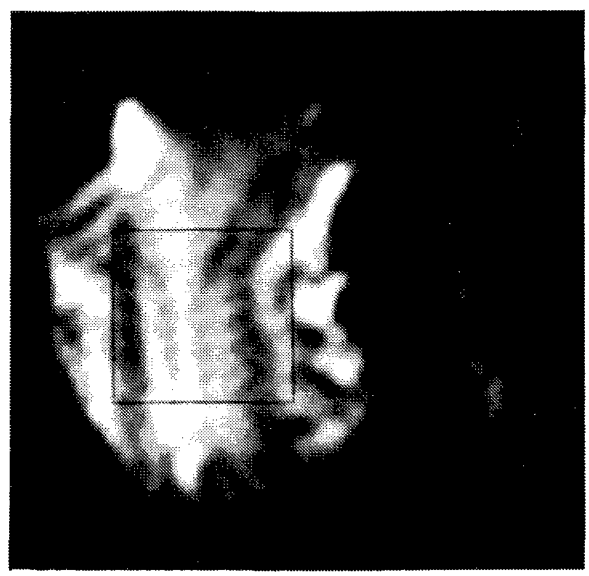

Figure 2: This is the single-shot 64 x 64 pixel EPI image corresponding to the preceding spin-warp image. The acquisition time was AT = 122 ms with TE = 140 ms. In this image, some distortions due to B_0 inhomogeneities are clearly visible, especially in the upper right corner. The longer echotime leads to enhanced T_2 contrast. However, the brain structures observed in the two images correspond. The black box marks the location of a 20 x 20 mm VOI.

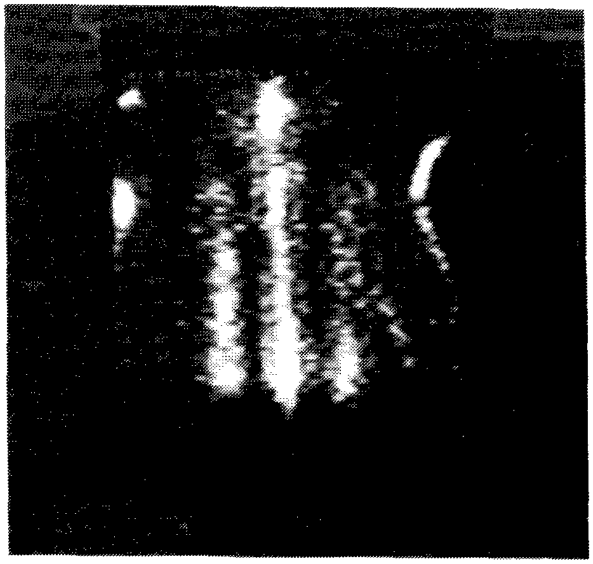

Figure 3: This is the zoomed 64 x 128 spin-warp image of a 20 x 20 mm volume selected in mid-brain. The field of view is reduced to 30 x 30 mm, thus yielding a resolution of 470 um x 235 um. 8 scans were accumulated for each phase-encoding step. In order to obtain an image contrast similar to the EPI images, the echotime has been set to TE = 140 ms.

Figure 4: Finally, this is the zoomed 64 x 64 EPI image of the same selected volume. The FOV being 30 x 30 mm, the pixel size is approximately 470 x 470 um. As the echo planar imaging gradients for a smaller FOV are stronger, the image distortion due to B_0 inhomogeneity is reduced, and not observable any more on this image. 8 scans were accumulated. The other imaging parameters were AT = 122 ms, TE = 140 ms.

Discussion and Conclusion:

The conspicuous ghost which sometimes appears in MBEST images is due to the asymmetry between even and odd echoes after the time reversal of alternate echoes. The time-consuming adjustment of acquisition parameters necessary to minimize the intensity of that ghost can be avoided by implementing new echo planar sampling schemes (*7*).

Since all the potential signal is utilized for image formation, EPI is an imaging scheme which is optimal in terms of signal to noise. It allows the acquisition of a complete image dataset in only one (or a few) shots, provided sufficient signal is detected. If this is not the case and a bigger number of acquisitions has to be accumulated, EPI still offers the advantage that the accumulation can be done in the frequency rather than the time domain, and that motion artifacts only translate into "smearing" of the image and not into the widespread diffuse artifact seen with conventional techniques.

By obtaining high resolution images of cat brain, we have demonstrated that the field inhomogeneity problem often encountered when using the EPI technique can be overcome through inner volume imaging. The principal hardware factor limiting this technique is the gradient switching time of the instrument, which might be remedied with the advent of new technologies (for instance (*8*)).

Bibliography:

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