Assessment of the limiting resolution in MRI

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Introduction: The limiting resolution is a basic quantity reflecting the fundamental performance of a MR system. Since resolution can be a determining factor governing lesion detectability, it represents an important parameter characterising the performance of a particular MR imaging sequence and protocol. Following the methodology initially developed for assessing the resolution of computed tomography (CT) systems, the gold-standard method for evaluating the limiting resolution in MRI involves the derivation of a modulation transfer function (MTF) from complex MR images, typically using the angled edge method of Judy.[1,2] Complex MR images are necessary for accurate characterisation of the MTF by this method since the magnitude operator rectifies the background noise fluctuations, resulting in a skewed line spread function (LSF) and an inaccurate MTF containing lower spatial frequency information displaced to higher frequencies. However, complex domain MR images are not readily accessible on some MR systems. Several alternative methods for assessing the resolution in MR have been suggested,[3,4] using either the modulation over a bar pattern or the width of the line spread function from the magnitude MR images, but to our knowledge these methods have not been quantitatively evaluated in comparison to the gold-standard method. The purpose of this study was to investigate several methods for determining the limiting resolution of a MR system in comparison to the established method of Judy and Steckner.

Methods: Imaging studies were performed with a 1.5 T GE TwinSpeed scanner (GE Medical Systems, Milwaukee, WI, USA), using a three-dimensional test object containing both an angled block for MTF assessment and resolution bar patterns with bar spacings of 1-2 mm.[5] Images were acquired with a spin echo/ fast spin echo sequence with TR/TE=2500/100 ms, FOV=25 cm, matrix=256x256, slice thickness=5 mm, for a range of echo train lengths (1, 4, 8, 12, 16, 24, 48, 64, 128). Resolution was assessed from the width of the complex MTF and the width of the complex and magnitude line spread functions derived from profiles taken over the angled block, and from the modulation over the bar patterns for both the phase and frequency encoding directions.

Results: The limiting resolution in the phase encoding direction is shown in figure 1. For each echo train length (ETL) the full width at half maximum (FWHM) of the magnitude line-spread function and the bar pattern modulation are plotted against the limiting resolution derived from the complex-domain MTF. Both the FWHM of the LSF and the bar pattern modulation are strongly correlated with the limiting resolution derived from the complex MTF, although this correlation is stronger for the bar pattern modulation (R=0.96 vs. R=0.82). Images of the test object acquired for three different ETL (1, 24, and 128) are shown in figure 2.

Discussion: As described previously, the limiting resolution worsens as the echo train length increases, showing significant degradation for ETL values greater than 10. Although the modulation over the bar patterns (defined as $\frac{M-m}{M+m}$, where M and m represent the maximum and minimum signal over the bar pattern, respectively) is normally used only as a discrete operator with a modulation of 50% as a threshold, these results show that it can be used as a continuous measure of resolution which is strongly correlated with the limiting resolution, and has the added advantage of being easily measurable on any scanner. Both the bar pattern modulation and the FWHM of the LSF can therefore be used to quantitatively characterise the limiting resolution of a MR system or protocol in cases where complex MR images are unavailable.

Figure 1. FWHM of the line spread function and bar pattern modulation vs. limiting resolution from the complex MTF

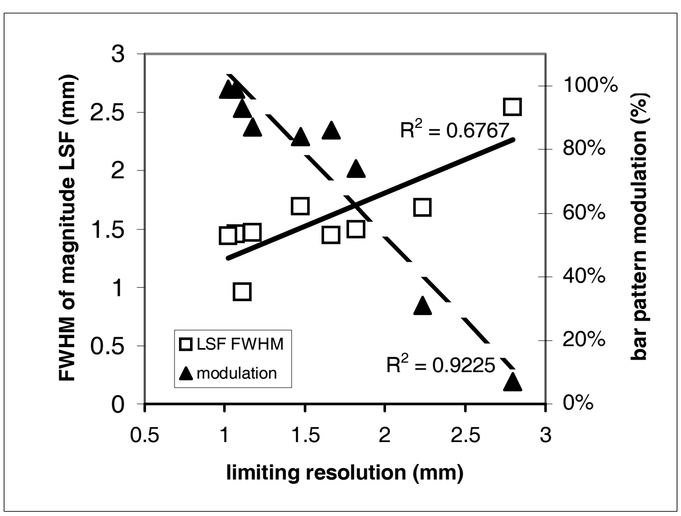
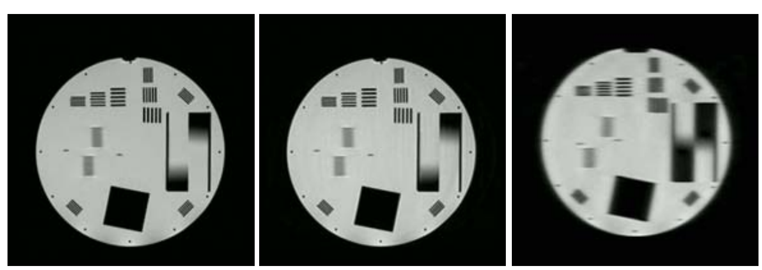


Figure 2. Images of the test object used for resolution assessment, acquired with ETL = 1, 24, and 128.



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