

A new single acquisition, two-image difference method for determining MR image SNR

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INTRODUCTION

There are many methods for computing MR image SNR, each with their own strengths and weaknesses. Specifically, the differences between methods relates to how the noise measurements are performed. Some methods use single images for fast measurements, but may not be able to provide reliable noise statistics [1]. Some methods acquire two images and perform an image subtraction to determine the noise statistics in the measurement region of interest (MROI) [2]. These methods are slower, but the noise measurements are believed to be more robust [1], unless system drift causes a change in signal intensity between the two images. Another dual image variant collects one signal image and one noise only image (rf transmitter off) [2]. This avoids system drift issues associated with dual image methods, but it can be argued that such a method does not fully capture all sources of noise. Other methods may use the mean [3] rather than standard deviation to compute the noise statistics because the squared term in standard deviation is more sensitive to subtle artifacts, and thus not as robust an estimate of noise.

A new single acquisition, two-image method for determining MR image SNR is presented which avoids the limitations of existing methods. The proposed method is a "difference of images" based technique where two images are produced in one acquisition using a two times larger readout field of view (FOV) size and a two times larger readout matrix size. Two "normal" unaliased FOV images are produced by splitting (undersampling) the even versus odd data points in the read direction into two separate raw data sets. After image reconstruction, standard "difference of images" SNR computations are applied.

METHODS

System drift in dual-image based SNR measurement methods is avoided by minimizing the time between identical points in k-space. One successful solution acquires the same phase encode in successive TR intervals [4]. The new method further reduces this time interval to the time separation between successive sampling points. If a single acquisition with two times larger readout FOV size and a two times larger readout matrix size is acquired, it is possible to then create two "normal" unaliased FOV images by undersampling the even versus odd readout data points into two separate raw data sets. Since the FOV was twice the "normal" size, and the undersampling operation halves the final image FOV, the final image should still be unaliased. If these two separate data sets are magnitude reconstructed, the first order phase progression in the read direction caused by the time shift between data points will be eliminated. Consequently, two images are produced where the time separation is effectively the sampling dwell time. Once these two images have been produced, standard "difference of images" SNR computations are applied. The only new features of this SNR measurement technique are the sequence and raw data manipulation steps. All other steps are identical to existing SNR measurement methods.

There are many possible methods for implementing this SNR sequence. Total sampling time can be held constant by doubling the sampling rate, in which case gradient amplitude will be the same as the "normal" FOV and sampled image. However, doubling the sampling rate results in a two times larger bandwidth and this may introduce subtle variations due to changes in the hardware and/or software filter stages. In addition, doubling the bandwidth may introduce frequency response variations associated with the receive coil bandwidth (coil Q). Alternatively, the sampling rate could be held constant, total sampling time doubled, and the gradient amplitude halved. Since most SNR sequences are low duty cycle, this doubling of sampling time will probably not increase total scan time. Signal loss may occur with the longer data sampling window, if sample T2 is very short.

RESULTS

The effectiveness of this new method is demonstrated by collecting a series of images over a range of slice thickness and observing how various SNR computation methods behave (figure 1). At low SNR levels, but not low enough to permit magnitude rectification of noise+signal, the various artifacts are masked by high noise levels, and all methods give the same result. As SNR increases the sensitivity to artifacts increases and the various methods start to produce different results. All data collected on a Hitachi Medical Corp. Airis Elite (Kashiwa, Chiba, Japan) 0.3T permanent magnet scanner with a four channel head coil and a single slice spin echo sequence (TE/TR = 140/800 ms, 4 KHz bw, 512x256 matrix size). Two acquisitions collected at each slice thickness with no time delay. The decimation process produced two pairs of images from each acquisition and seven different SNR measurements were computed, some with multiple measurements. The seven SNR measurements are broken into the three possible measurements using the full (two times FOV) images and the four possible measurements using the decimated images: **1)** single image SNR of full (two times FOV) image, using mean of a background region as a noise estimate (two estimates), **2)** single image SNR of full (two times FOV) image, using the std. dev. of a background region as a noise estimate (2e), **3)** "difference of image" SNR of full (two times FOV) image (2e), **4)** single image SNR of the decimated image, using mean of a background region as a noise estimate (4e), **5)** single image SNR of the decimated image, using the standard deviation of a background region as a noise estimate (4e), **6)** "difference of image" SNR of the decimated image (2e) – the recommended new SNR measurement technique, **7)** "difference of image" SNR of the decimated image, across acquisitions (4e). Twenty SNR data points were generated at each slice thickness. The results of all seven methods were statistically normalized, assuming Rician noise statistics. For the purposes of the comparison, the reference is the single, normal FOV, image.

The largest divergence is the "difference of two times FOV images" method (#3), where the individual images have the highest intrinsic SNR (highest sensitivity to system drift) and where the two images are separated in time. The second largest divergence is produced by the "difference of images" SNR measurement (#7) where the difference in acquisition time is the only relevant factor. Since there are fewer data points (decimated data sets) the intrinsic SNR is lower than #3. By eliminating the time difference between acquisitions (#6 – the recommended method) the results improve dramatically and produce the highest SNR estimates. The recommended method has the highest slope (highest SNR) because it has effectively eliminated sources of drift. The correlation coefficient is $r^2 = 0.999$ for all five linear fits.

CONCLUSIONS

A new method for computing image SNR has been developed which is robust against system drift by sequence design and data handling manipulations. Results demonstrate that the method produces the results that are theoretically expected.

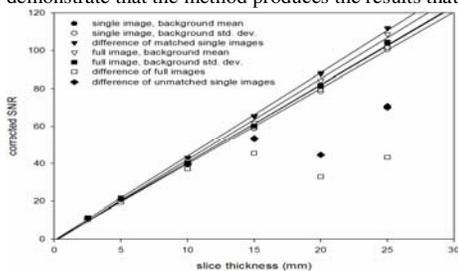


Figure 1. SNR (corrected) versus slice thickness for seven different methods of SNR estimation.

REFERENCES

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