Comparison of SNR Calculation Methods for in vivo Imaging

B. Wu[1], C. Wang[1], Y. Pang[1], and X. Zhang[1,2]
[1]Radiology&Biomedical Imaging, University of California, San Francisco, San Francisco, CA, United States, [2]UCSF/UC Berkeley Joint Group Program in Bioengineering, CA, United States

Introduction

Local and global SNR of in vivo MR images are often measured to evaluate the image quality. Many commonly used SNR measurements, such as the methods in NEMA standard [1] are based on phantom images. Due to the density variation of in vivo images, the motion during the acquisition and other aspects, the SNR measurement of the in vivo image, especially at high field MRI, is much more complicated. Therefore, the methods based on phantom images may not be applicable for in vivo images. The purpose of this work is to evaluate and compare SNR calculation methods to provide the reference or guidance for in vivo image SNR measurements.

Method

Four SNR calculation methods are evaluated in this work. Two methods are followed with NEMA standards by acquiring an additional in vivo image or noise image, individually. In NEMA method 1, the standard derivation (SD) of the noise is obtained from the subtraction of two acquisition phantom images. The measurement region of interest (MROI) should cover at least 75% of the area of the image of the signal-producing volume of the phantom. This method is extended here for in vivo image SNR measurement. NEMA method 2 acquires a noise scan image with the sample in its original position and with no RF excitation. This permits a reduced scan time for the noise image because TR can be reduced to a minimum without any effect on the image. Standard deviation of the noise is directly calculated from this noise image. Two other commonly used methods with a single acquisition image are also compared. The mean or standard deviation of a selected area in background is calculated as the noise. Those four SNR calculation methods are listed in the table.

Method 1 (NEMA #1)	Method 2 (NEMA #2)	Method 3	Method 4
$SNR = \sqrt{2}\,\frac{S_{image1}}{SD_{\lvert image1-image2 \rvert}}$	$SNR = 0.66\,\frac{S_{image}}{SD_{noise.image}}$	$SNR = \frac{S_{image}}{Mean_{background}}$	$SNR = \frac{S_{image}}{SD_{background}}$

Those SNR calculations were performed with a Nova 8-ch human head array at 7T. We designed a method for fair and rigorous comparison. Two sets of human head images with different number of excitation (NEX=1 and NEX=2) were acquired. Two human head images and one noise image were obtained with NEX=1 and NEX=2. The SNR with NEX=2 should be theoretically 1.414 times higher than that with NEX=1 [2]. So the SNR ratio SNR^{NEX2} / SNR^{NEX1} was then calculated and the ones approaching 1.414 indicate the good performance. Images in our experiment are all 256×256 in size. Except NEX, we kept all other parameters the same including the same scale of gray level. In methods 3 and 4, the position and the size of the selected area in image background may affect the calculation, so we choose 9 different positions with 3×3, 5×5, 7×7 and 9×9 pixels in the background to evaluate the consistency of the methods.

Results

Method 1: subtracted image from the two head images is shown in FIG 1a. Due to the movement of the patient and the temporal instability of the scanner, several artifacts within the head region may increase the standard deviation. The ratio of SNR^{NEX2} / SNR^{NEX1} is calculated as 2.040, which is far from the reference value 1.414.

Method 2: the noise image is shown in FIG 1b, which has the same scale as FIG. 1a. The calculated SNR^{NEX2} / SNR^{NEX1} is 1.405.

Method 3: as indicated in FIG 2a, the size of the selected background block may significantly affect the results. Smaller size of blocks such as 3×3 and 5×5 result in unstable calculated SNR, larger size of blocks has better consistency.

Method 4: as shown in FIG 2b, SD of the image background with different positions and sizes results in inconsistent calculations.

Conclusions

The accurate measurement of the noise is critical for SNR calculation. The method 2 by directly acquiring an additional noise image exhibits the best performance for the noise calculation, resulting in a more accurate SNR calculation. In this method, the required noise image can also be generated by simply calculating the noise through the background mean value of an image (method 3). However, for measurement accuracy, small geometric area selected for noise measurement should be avoided. 7×7 or larger blocks in our experiment indicates a better and more reliable performance in SNR calculations. Methods 1 and 4 are not suggested for in vivo SNR calculations.

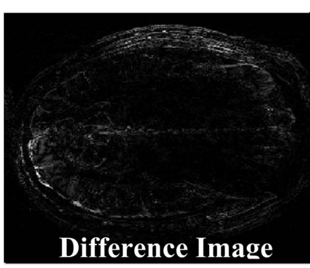

FIG 1a

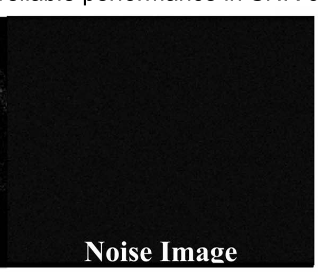

FIG 1b

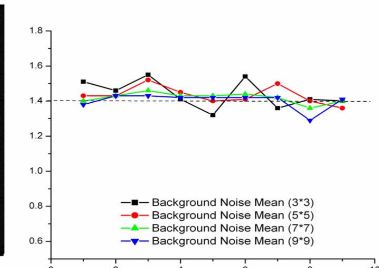

FIG 2a

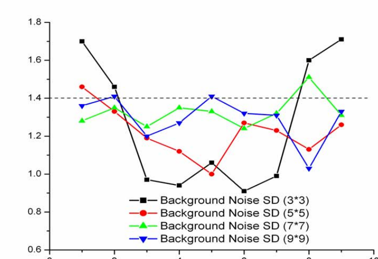

FIG 2b

Acknowledgements

This work was supported in part by NIH grant R01 EB004453, UC Discovery ITLbio04-10148 and QB3 Award.

References [1] NEMA standards publication MS-2001 [2] Traficante DD. Concepts in Magnetic Resonance, 1991, 3, 83-87.