Multiple Half-NEX Fast Gradient Echo for Reduced Free Breathing Artifact In Cardiac Imaging

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Introduction

There are many applications that benefit from signal averaging (multiple NEX). Signal averaging has two principle benefits: motion artifacts decrease as the number of averages increases; and signal-to-noise (SNR) increases by the square root of the number of averages. However, these benefits comes at the expense of scan time. In cardiac applications, breath-holding is used to eliminate or reduce respiratory motion. In many cases this is not practical or possible because of the patient's health, age, or compliance. In these situations, one simple option is a free breathing, multiple NEX scan to average out the respiratory motion artifact. The number of signal averages used is dependent on the application, but 4 to 8 works well (2). To minimize scan time during free breathing, partial Fourier acquisition (half-NEX) can be used. To reduce the motion artifacts, a multiple half-NEX technique is proposed that does not require the use of partial Fourier reconstruction and does not suffer a degradation of spatial resolution.

Methods

In the generic sense, signal averaging consists of averaging repeated acquisitions of all required k-space data (YRES), followed by image reconstruction. Multiple half-NEX (MHN) is a signal averaging technique that has the important features of collecting all lines of k-space, while over sampling the center of k-space. MHN does not require partial Fourier image reconstruction as alternate halves of k-space are acquired in each signal average, yielding a complete k-space data set. MHN can be applied to various phase ordering schemes, including sequential, interleaved, segmented, and non-segmented. The number of half-NEX signal averages may be varied from 2 to n, and is limited only by the constraints associated with scan time. The number of lines of k-space acquired for a MHN scan is defined in generalized Equation 1.

Equation 1

$$\text{Lines of k-space} = \sum_{j=0}^{n-1} (YRES/2 + OVERSAMPLES)_j = (YRES/2 + OVERSAMPLES) * n$$

When j is an even number, k-space is filled beginning at line 1 and stopping at line (YRES/2 + OVERSAMPLES). When j is an odd number, k-space is filled beginning at line YRES and stopping at line (YRES/2 – OVERSAMPLES + 1). This alternating acquisition pattern is used until n averages have been acquired and summed. This even/odd k-space sampling technique results in all lines of k-space being summed n/2 times with the center OVERSAMPLES*2 lines of k-space being summed n times, which is the same as normal signal averaging. The number of OVERSAMPLES will vary based on the phase ordering scheme and value for YRES. For non-segmented phase encoding schemes, 4 to 8 OVERSAMPLES is sufficient, and for segmented schemes, generalized Equation 2 defines the number of OVERSAMPLES.

Equation 2

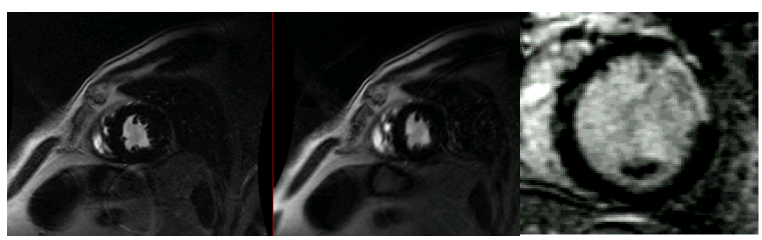
$$\text{OVERSAMPLES For Segmented Phase Ordering} = (\text{INTEGER})(YRES/2/VPS + 1) - YRES/2$$

Where: VPS is the number of lines of k-space acquired per cardiac (R-R) segment

MHN can also be used in a breath-hold scan with a 2 half-NEX acquisition. This specific implementation over-samples the central k-space views twice, thus reducing any motion related artifacts from breath-hold inconsistencies. The scan time is slightly increased but the benefit of a multiple NEX acquisition is realized without the concomitant doubling of scan time.

Results and Conclusions

As most of the image signal power resides in the central k-space views, over-sampling the central k-space views provides a means to average out or reduce motion-related artifacts. Multiple half-NEX is an effective method to reduce this class of artifact (Figure 1a &1b), while increasing signal-to-noise (SNR), at a reduced scan time compared to conventional signal averaging (Table 1). There are indications of improved contrast for 2 half-NEX, breath hold, 2D Myocardium Delayed Enhancement (MDE) scans, as compared to 1 NEX scans (Figure 1c). A clinical study is planned to investigate the effectiveness of 2 half-NEX imaging for MDE.



1a: 2 half-NEX Breath Hold | 1b: 8 half-NEX Free Breathing | 1c: 2 half-NEX Breath Hold

Figure 1: 1a & 1b show a comparison, from the same 45 year old patient, of a breath hold, 2 half-NEX, 2D MDE versus a free breathing 8 half-NEX, 2D MDE. As expected, motion artifact is greatly attenuated with apparent blurring in the free breathing image. The images are cardiac gated, IR prepped, Ti = 250 msec, 256x160, 8 mm thick, 32x32 cm FOV, 24 VPS, 2 RR, delay time = 15 minutes, double dose of Gadolinium contrast agent. 1c shows an anterior lateral wall transmural infarction. A GE 1.5T, 11.0 Excite scanner, with 8-channel phased array coil is used.

Table 1: Scan Time (seconds), YRES = 160, Heart Rate = 70 BPS, 1 RR

Views Per Segment	**8**	**12**	**16**	**20**	**24**
1 NEX	17.2	12	8.6	6.9	6
8 NEX	137	96	68.6	54.9	48
8 half-NEX	75.4	48	41.2	34.3	27.4

References

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