A Comparison of Three SPRITE-Based Techniques for the Quantitative 3D Imaging of the ^{23}Na Spin Density on a 4T Whole-Body Machine

S. Romanzetti[1], M. Halse[2], J. Kaffanke[1], J. Rioux[2], B. J. Balcom[2], N. J. Shah[1]

[1]Institute of Medicine, Research Centre Juelich, Juelich, Germany, [2]Department of Physics, Univeristy of New Brunswick MRI Centre, Fredericton, NB, Canada

Introduction

The second most abundant MR-active nucleus in biological tissue, ^{23}Na, is present in very high concentrations. This, combined with its large variations between healthy and diseased states, makes it a very attractive nucleus to image. Being a spin 3/2 nucleus means it is quadrupolar and therefore has a fast-relaxing component in restricted environments. Conventional imaging sequences are ill-suited for the observation of the fast-decaying component. Therefore, imaging fast-decaying nuclei in biological tissues demands unconventional strategies. The SPRITE technique, developed over the past few years for non-biological imaging, is one such method that allows the formation of images from fast-relaxing species [1]. By sampling only one point, following RF excitation, convolution of the signal with T_2^* decay is avoided and high resolution images of a population of fast-relaxing spins can thus be achieved. However, the single point sampling scheme is inefficient and hence SPRITE suffers from long acquisition times. Two centrically ordered sampling schemes, Spiral-SPRITE and Conical-SPRITE, have been employed to increase the sensitivity of SPRITE and to provide quantitative spin density information [2].

Methods

Standard SPRITE, Spiral-SPRITE and Conical-SPRITE imaging methods were implemented on a Varian 4T UnityInova system equipped with a 40 mT/m whole-body gradient system. Standard SPRITE employs rectilinear sampling, acquiring a single datum point at each location in k-space separately. Spiral-SPRITE and Conical-SPRITE employ centrically ordered sampling schemes whereby the total gradient areas are carefully chosen to ensure that the resulting data points lie on the Cartesian grid facilitating use of the standard FFT for image reconstruction. Images were acquired with a matrix of 32x32x16, t_p = 180µs, TR = 4.0ms, flip angle = 10°, 4 averages, FOV = 240x240x240mm and a nominal resolution of 7.5x7.5x15 mm. Five multiple points were acquired with a dwell time of 12µs in each of the 4 scans. The images from each of these multiple points were reconstructed to a common FOV by use of the chirp-Z transform and signal averaged in image space. Total image acquisition times varied dramatically between the three imaging schemes. The acquisition times were 35 minutes, 192 s and 102 s for standard SPRITE, Spiral-SPRITE, and Conical-SPRITE, respectively.

Results

Figures 1a, 2a and 3a show 2D slices from a 3D ^{23}Na data set obtained using standard SPRITE, Spiral-SPRITE, and Conical-SPRITE, respectively. The five samples were quasi-spherical agar gel phantoms with sodium concentrations ranging from 50 to 250 mM. Figures 1b, 2b and 3b present plots of the mean image intensity in regions-of-interest within each phantom, as a function of ^{23}Na concentration, for each of the images in Figures 1a, 2a and 3a, respectively. The sixth datum point in the plots is the mean intensity of the background noise in each image. Visual inspection of the images in Figures 1-3 shows differences; image quality and SNR are the highest in the Conical-SPRITE image.

Discussion

The suitability of the SPRITE technique, in the three different guises presented here, for clinical applications rests on consideration of the quantitative information output compared with acquisition time. The Conical-SPRITE acquisition shows relatively few image artifacts and, moreover, the intensity across the homogeneous phantoms is more uniform than for the other two methods. The quantitative measure of the sodium density, as determined by the three methods, does not differ significantly; Conical-SPRITE performs slightly better. The massive reduction in acquisition time for Conical-SPRITE compared with standard SPRITE is an advantage which will prove critical for clinical applications. Despite the reduced acquisition time, the quality of the fit is a little better, and by virtue of centric scanning, the SNR is slightly improved. In conclusion, the overall advantages of Conical-SPRITE for potential clinical applications are: smaller SAR because fewer RF pulses are needed; acquisition time reduced by a factor of ~ 20 over standard SPRITE; less sensitivity to motion artifacts; reduced demands on the gradient system; and, unlike conventional conical or spiral imaging, standard FFT reconstruction may be used since points are acquired on the Cartesian grid.

References

[1] B. J. Balcom, SPRITE Imaging of Short Relaxation Time Nuclei, in "Spatially Resolved Magnetic Resonance", pp. 75-86, Wiley-VCH, Toronto (1998)

[2] Meghan Halse, David Goodyear, Bryce MacMillan, Pavol Szomolanyi, David Matheson and Bruce J. Balcom, JMR, *in press* (2003)

Figure 1a

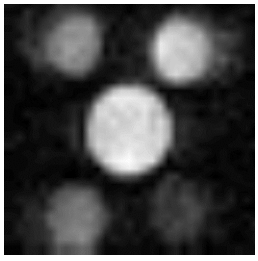

Figure 1b

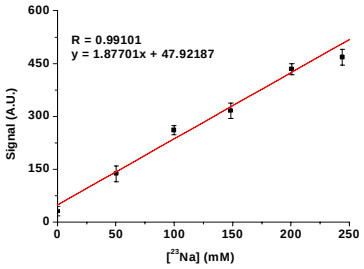

Figure 1: (a) 2D slice of 3D ^{23}Na SPRITE image acquired in **35 min**. (b) Plot of signal intensity as a function of ^{23}Na concentration.

Figure 2a

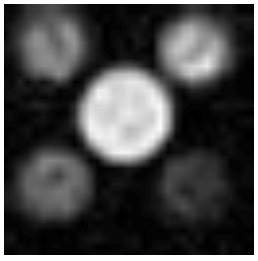

Figure 2b

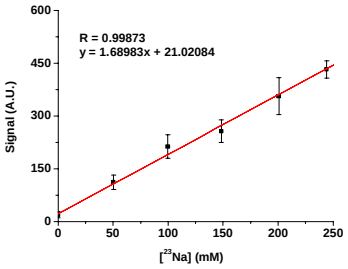

Figure 2: (a) 2D slice of 3D ^{23}Na Spiral-SPRITE image acquired in **192 s**. (b) Plot of signal intensity as a function of ^{23}Na concentration.

Figure 3a

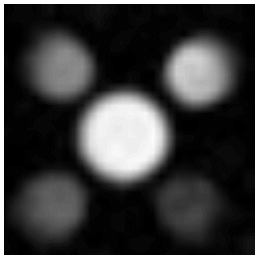

Figure 3b

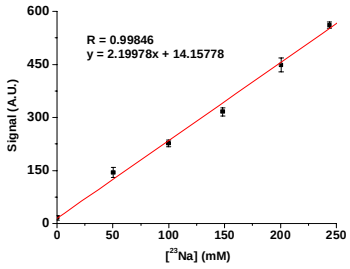

Figure 3: (a) 2D slice of 3D ^{23}Na Conical-SPRITE image acquired in **102 s**. (b) Plot of signal intensity as a function of ^{23}Na concentration.