Dynamic Contrast-Enhanced Breast MRI using Dual-Resolution 3D Spiral Imaging

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Introduction:

Dynamic contrast-enhanced (DCE) imaging is a powerful technique for diagnosis and assessment of breast cancer, and is standard in breast MRI protocols [1]. However, DCE imaging is limited by the tradeoffs between spatial and temporal resolution. Techniques to improve the spatiotemporal resolution tradeoffs, including time-resolved imaging of contrast kinetics [2] and k-space weighted image contrast (KWIC) [3] are promising options for Cartesian and radial imaging. Spiral imaging generally allows 3-4 times faster k-space coverage than Cartesian for equivalent resolution [4]. Here we present the design and implementation of dual-density spiral imaging to allow imaging of contrast enhancement simultaneously at two different spatial and temporal resolutions.

Methods and Results:

Although spiral imaging with both low and high resolution has been described for DCE breast imaging [5] our goal here is to acquire a continuous 3D image series at two spatial resolutions. We designed a spiral readout trajectory as shown in Fig. 1 with a density that decreases by 5 for the outer half of k-space using a numerical method [6], with careful compensation for density during reconstruction [7]. We use 45 such spiral interleaves to reconstruct the high-resolution images. By ordering these 1, 6, 11, …, 41, 2, 7, 12, …, 42, 3, …, 43, …, full-field-of-view (FOV) low resolution images can be reconstructed at five times the frame rate using only 9 interleaves at a time, i.e. interleaves 1, 6, 11, …, 41 for the first image, then 2, 7, 12, …, 42 for the second, and so on.

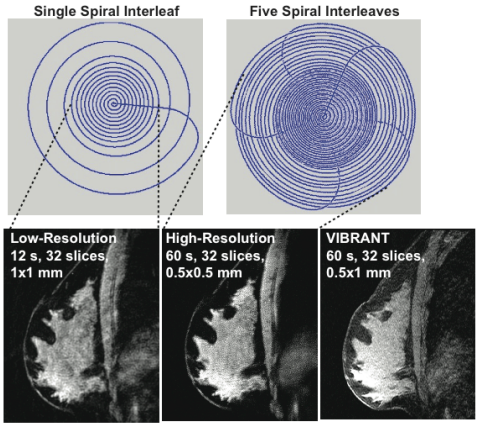

Figure 1: *Dual-resolution spiral trajectory – the inner density of one interleaf is matched by the outer k-space density with five interleaves. Using the inner-half-radius of k-space and 9 interleaves allows 3D images with 12-second frame rates, while 45 interleaves with full k-space radius gives 60-secod frame rates. Intermediate resolution Cartesian "VIBRANT" images are also shown for comparison.*

We tested this technique in 5 volunteers on 1.5T and 3.0T GE Excite systems with 50 mT/m gradients and 150 mT/m/ms rise times, with 32 sagittal slices, 3mm thick, over a 20 cm FOV. Robust fat suppression was provided by a water-only excitation. Sample 3D low (1.0x1.0 mm) and high (0.5x0.5 mm) resolution images, every 12 and 60 seconds are shown in Fig. 1, which shows a comparison with VIBRANT, a 3D Cartesian technique with 1.0x0.5 mm (A/P x S/I) resolution and 31 kHz readout bandwidth, which had a scan time of 60 seconds using intermittent fat saturation. Note the differences in resolution between spiral images, the comparable A/P resolution between the high-resolution spiral and VIBRANT scans, and the improved fat suppression of the water-only excitation.

We have also applied this technique with gadolinium contrast injection in 4 patients. The contrast injection is 40 seconds into an 8-minute acquisition that provides 8 high-resolution images, with an example in a patient with invasive ductal carcinoma shown in Fig. 2. Eight consecutive low-resolution images starting 20 seconds after injection are shown in the lower figure, showing enhancement detail between time points b and c in the upper figure. Note that the combination of low and high-resolution images shows the enhancement pattern of the tumor, and no view sharing is used. High-resolution images could also be reconstructed centered at every low-resolution time point. All human subject scans were approved by our institution's IRB.

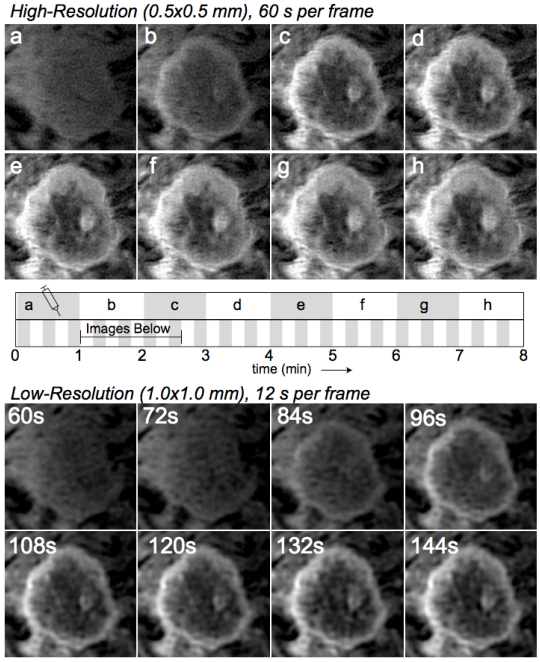

Figure 2: *Dual-resolution spiral images at 3.0 T (zoomed to tumor) show contrast uptake in an invasive ductal carcinoma with mucinous features. High and low spatial resolution images are acquired every 60 s and 12 s respectively. The acquisition provides detailed information about the heterogeneous contrast uptake.*

Discussion:

The additional time for dual resolution results in a 25% increase compared with low-resolution scanning, and 40% increase compared with high-resolution alone. In future this technique can be combined with parallel imaging to simultaneously image both breasts in the same scan time, while the addition of off-resonance correction will further sharpen the images. Alternatively, the low/high resolution trade-off can be modified for different temporal rates, as well as different pixel size ratio between the different resolutions. Ultimately, this technique may avoid the need to have multiple scans with different temporal and spatial resolution during DCE breast imaging, which will simplify protocols and offer more diagnostic information.

References:

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