In Vivo Imaging Using Liquid Nitrogen Cooled Phased Array at 3.0T

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Introduction

Liquid nitrogen (LN_2) cooled RF coils had been shown to improve SNR over room temperature coils at 1.5T [1-3]. LN_2 cooling to 77K reduces coil noise through the lowering of coil resistance and coil temperature. In theory, if coil noise dominates the total noise, there is a SNR gain of about 280% in the LN_2 cooled coil relative to the room temperature coil [1]. However, since sample noise increases with resonance frequency and coil size, to keep sample noise significantly lower than coil noise at 1.5T or higher fields, coils are restricted to a few centimeters in size. This leads to the development of LN_2 cooled array coils that provide larger field-of-view (FOV) coverage while maintaining SNR [2]. Recently, with the availability of well-developed 3.0T MRI systems, 3T imaging is becoming more widely used for both clinical and research purposes. It is our objective to design, construct and test a LN_2 cooled array coil at 3.0T, and compare its imaging performance with a similar room temperature coil.

Methods

The study was conducted on a Siemens Trio 3.0T whole body MR scanner. Two identical linear dual arrays were developed and were separately tuned to 123.20 MHz and matched to 50 ohms at room temperature and LN_2 temperature. Decoupling among the coil elements was achieved using partial overlapping of the elements. Individual coil elements in the arrays were constructed using 14-gauge copper wire, formed into rounded square shape and mounted on a printed circuit board that does not deform at LN_2 temperature. The size of each coil element is 3.5cmx3.5cm. Each array was placed inside a plastic container able to hold liquid nitrogen. A 2mm thick Styrofoam was used to provide thermal insulation for the object scanned using the LN_2 cooled array. In vivo imaging studies were conducted on a normal volunteer whose fingers were placed under the coil arrays during scans. The separation between the coil arrays and the fingers was about 1cm. A deceased adult mouse was also imaged using the coil arrays. In addition, a phantom filled with vegetable oil with negligible sample noise was imaged to obtain the maximum achievable SNR gain. Similar tests were also conducted using the room temperature array under identical scanner's settings for comparison.

Results

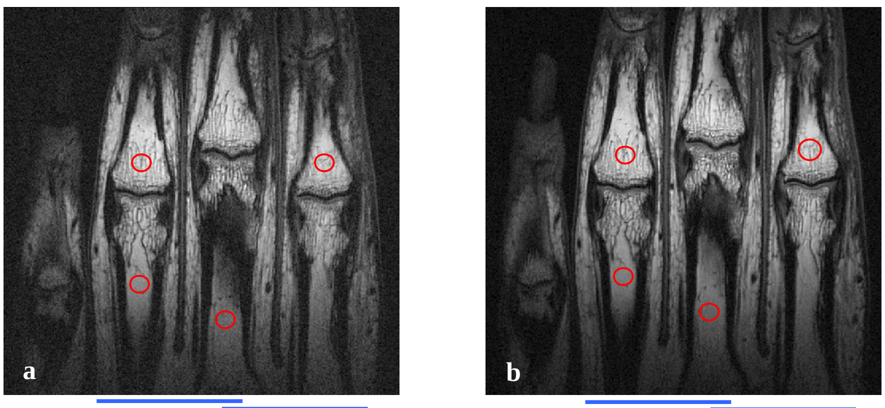

Figure 2. In vivo spin-echo (SE) images of fingers obtained using (a) the room temperature array and (b) the LN_2 array. Imaging parameters are TR/TE = 1000ms/15ms, FOV 10cm, slice thickness 1mm, matrix size 512x384 and scan time 6:24 minutes.

The orange circles indicate the ROIs for signal intensity measurements while the blue bars underneath show the position of individual coil elements.

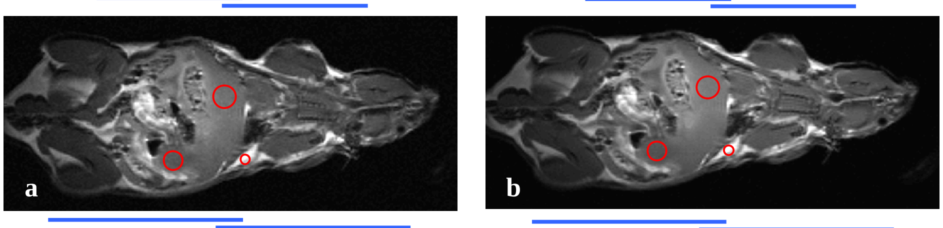

Figure 3. Mouse SE images obtained using (a) the room temperature array, (b) the LN_2 array. The imaging parameters are TR/TE = 500ms/13ms, FOV 10cm, slice thickness 1mm, matrix size 256x256 and scan time 2:08 minutes.

The image data shows obvious SNR gain of the LN_2 array over the room-temperature array. The average SNR gain, as measured from the multiple ROIs, is 214% for the fingers, 209% for the mouse and 240% for the oil phantom.

Discussion & Conclusion

In this study, we have designed, built and tested a LN_2 cooled phased array coil for 3.0T. The image data show that it provides a SNR gain factor of up to 240% compared with their room temperature counterparts. Our SNR gains do not reach the theoretical value of 280% due to noises from preamplifier, cable and sample. In addition, non-magnetic chip capacitors of relatively high values (in order of 100 pf) have to be used to build the coils, and their Q factors are relatively low (in hundreds) at 123MHz. Compared with high-temperature super-conducting (HTS) coils, LN_2 cooled coils provide the advantages of simpler array construction and flexible 3-dimensional shapes for volumetric coverage. Though flexible HTS tape/wire have also been used for RF coils, their super-conducting properties degrade rapidly in high magnetic field [3]. Besides, the Q-performance of HTS materials depends on static magnetic field orientation thus limiting the HTS coil applications [3]. Furthermore, HTS coil performance is more easily affected by sample loading, and a small sample loading (eg. one that drops the room temperature Q factor by 10%) can bring the SNR gain in HTS coils close to that of LN_2 coils [1]. Some possible applications of LN_2 cooled arrays include high-resolution clinical imaging of joints, skin, eyes, and superficial vessels. They can also be used in MR microscopy of small animals for human pathology modeling. Our future work includes increasing the number of coil elements to provide even larger FOV coverage, and to combine LN_2 coils with parallel imaging techniques to save imaging time.

Reference

1.Wright AC, et al. Magn Reson Med 2000;43(2):163-169. 2.Kwok, WE, et al. ISMRM 2002, p.879. 3.Darrasse L, Ginefri JC. Biochimie 2003;85:915-937.