Comparison of Surface Coil and Automatically-tuned, Flexible Interventional Coil Imaging in a Porcine Knee

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Introduction There is a great deal of prior work regarding the advantage of using a surface coil versus a body coil to achieve high local SNR [1,2]. But there is not yet a careful, experimental comparison between surface coils and electronically tuned interventional coils. Here we present results from an *in vitro* porcine knee study comparing high resolution images from a 3-inch surface coil and a minimally invasive, automatically tuned, 1-inch flexible interventional coil.

Early experiments reveal that, even at 1.5T, a closely-fitted birdcage coil will achieve higher SNR for structures beyond 6cm deep than will any size of conventional surface coil [3]. To do better one can place a smaller, invasive probe closer to the region of interest. Under controlled probe shape and loading conditions, such as with endorectal and intravascular imaging, this has worked well [4,5]. However, more general interventional coils require remote operation and a variable shape, which both introduce practical problems with tuning and matching. Our prior work provides analysis of such issues, and circuitry for automatic tuning of a flexible interventional probe [6]. We used this hardware (figure 1) to collect images for comparison against a 3-inch surface coil.

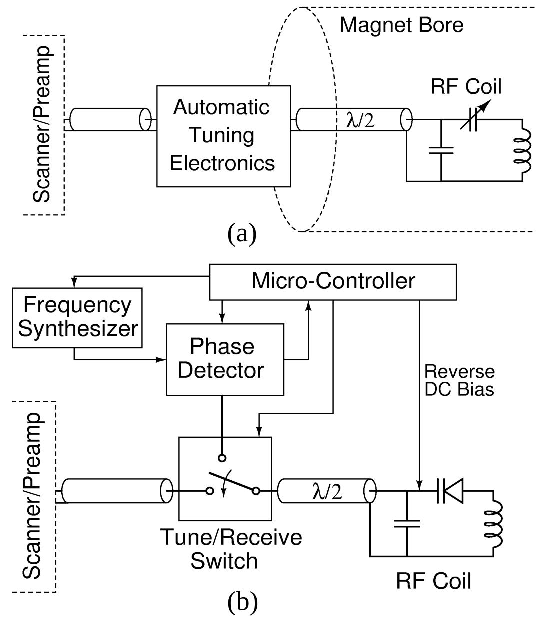

Figure 1: (a) Experimental setup. (b) Automatic tuning electronics. The phase detector relays coil tuning condition to the micro-controller, which automatically adjusts the RF coil tuning with a DC voltage.

Methods To evaluate the performance of our flexible, 1-inch interventional coil, we imaged the patella-femoral cartilage and condylar notch of an *in vitro* pig knee in a GE Signa 1.5T scanner. In each case, we first placed a 3-inch surface coil over the patella and imaged using standard 3D FIESTA (SSFP) sequences of $6cm^2$ and $15cm^2$ FOV (30 degree flip, 0.7mm and 1mm slice, 256^2). After removing the surface coil, we surgically implanted the flexible coil within the interarticular space of the patella-femoral joint. We performed electronic autotuning of the coil after implantation, and imaged using identical scan parameters. Finally, we repeated the whole process after implanting the coil in the posterior condylar notch between the femur and the tibia. We measured the SNR of the complex image data using MATLAB (Mathworks, Inc.).

Results The SNR of images with the flexible coil was substantially higher than the SNR of the surface coil images in all cases. Figure 2(a,b) displays similar slices of the same pig knee—with identical scan parameters—from the surgically-implanted coil and from the 3-inch surface coil. The flexible coil exhibits SNR gains by a factor of 3 within the center of the patella-femoral cartilage (9.5 vs. 3.1, +/- 0.2). The images of the posteriorly located intracondylar notch are in figure 2(c,d). Here, the flexible coil's SNR remains above 10, while that of the surface coil falls below 2.

Conclusion As expected, the smaller coil produces images with superior SNR to those of the 3-inch coil. Comparing it within the best ROI of the 3-inch coil (patella-femoral cartilage) we might predict a factor of $3^3/2 = 13.5$ increase in SNR due to shrinking the coil diameter by a factor of three, and doubling of the effective noise volume (because the smaller coil is surrounded by tissue). However, this presumes that inductively coupled sample noise dominates. Loaded/unloaded Q measurements of our small coil suggest that conductive and dielectric losses are also important. Hence, we find that the factor of 3 increase in SNR is reasonable.

The real benefit of using a small, flexible interventional coil for clinical work is that it retains high local SNR for arbitrary depths of target anatomy if well-matched to the preamplifier. With automatic tuning, we can maintain this SNR while allowing the coil to conform to anatomy. We have shown this to be true with our system. For a 7cm target depth, we witness SNR gains near an order of magnitude versus a 3-inch surface coil. This enables resolution increases by a factor of 2-3 without sacrificing either SNR or scan time. Clinically, these gains could make the difference between a minimally-invasive image-based diagnosis, and arthroscopy in cases such as cartilage flaps or transplants.

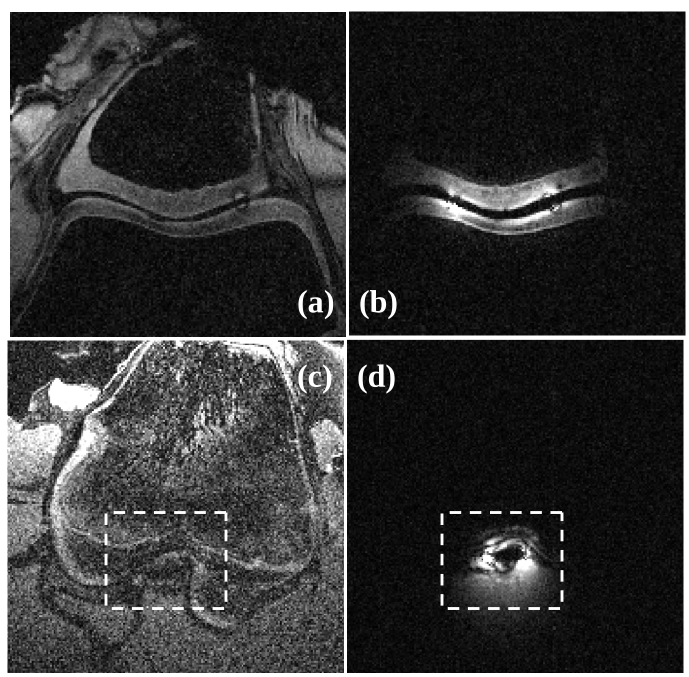

Figure 1: Comparison 3D FIESTA (SSFP) images from 3-inch surface coil (left) and 1-inch flexible coil (right). (a,b) patella-femoral cartilage, $234 \times 234 \times 700 \mu m^3$, $6cm^2$, 2:47, SNR=3.1 vs. 9.5. (c,d) condylar cartilage, $586 \times 586 \times 1000 \mu m^3$, $15cm^2$, 1:17, SNR=1.8 vs. 10.2.

References

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