A Four-coil Phased Array Coil for High Resolution MR Imaging of the Knee

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Introduction
Linear and quadrature local RF coils have been commonly used in the evaluation of knee pathology. Even though their performance in diagnosing meniscal pathology in clinical setting is very adequate, they fall short in the evaluation of articular cartilage pathology. The improved signal sensitivity of phased array coils supporting higher image spatial resolution has in recent years made them an attractive option for musculoskeletal MR imaging. Since there is a great clinical need for higher performance knee coil, we designed and built a four-coil phased array coil specifically for imaging the knee. We evaluated its RF properties and compared its imaging performance with a General Electric (GE) extremity coil.

Method
A four-coil phased array receiver was constructed using shape and dimensions that are suitable for imaging the knee of a normal adult (Fig.1). Each coil element was built from copper wire (gauge #11) to form a square of 12cm long. Three coil elements were mounted on and supported by a plastic form (Fig.1). A separate fourth coil element was placed posteriorly to the knee. Each coil was individually tuned under loading to 63.85 MHz. The coupling between coil elements were reduced by partial coil overlapping and by using blocking circuit design described in [1,2]. The commercial coil to be compared with was a GE transmit/receive 6.5" diameter linear lower extremity coil (Milwaukee, WI).

![Figure 1. Sketched diagram of the four-coil phased array](image)

The coils were tested on a phantom and a normal volunteer using a 1.5 T GE Signa Horizon MR scanner (Milwaukee, WI). The phantom used in this study was made up of saline solution in a cylindrical plastic bottle of 11 cm in diameter. In the phantom test, spin echo sequence was used with TR/TE of 600/14ms, 16x16cm FOV, 3mm slice, 256x192 matrix and 1 NEX. The images were evaluated for S/N, signal uniformity and artifacts. Normal volunteer knees were imaged using double-echo spin echo sequence at sagittal planes with TR/TE1/TE2 of 2000ms/13ms/80ms, 11x11cm FOV, 2.5mm slice, 256x192 matrix, 1 NEX and 7.20 minutes imaging time. This sequence is in use in our routine clinical protocol for knee imaging using a phased array coil.

Results
In the phantom study, the S/N measured using a 1cm square ROI at the center of the coil was 31 for the phased array coil and 16 for the GE extremity coil. The S/N along a vertical line measured at the center of the phased array coil was plotted (Fig.2).

![Figure 2. Plot of S/N versus distance from the top of the coil](image)

In the normal volunteer study, the phased array coil gave better S/N over the GE extremity coil in all locations evaluated: muscles, femur, tibia, articular cartilage and patella.

The phased array coil with the separate posterior coil element removed was also tested and found to have decreased signal uniformity and degrade in image quality in both the phantom and the volunteer studies.

Conclusion and Discussion
This study showed that our specially designed multi-coil phased array coil gives significantly better S/N than the GE extremity coil. In the phantom study, the S/N at the center of the phased array coil was about twice that of the GE extremity coil. The S/N improvement was even higher off-center. However, the GE extremity coil was more homogeneous with signal variation of within 20% while that for the phased array coil was about 40% on a central axial slice.

In the normal volunteer study, the phased array coil gave significantly better S/N at various anatomical locations including muscles, femur, tibia, articular cartilages and patella. In fact, our clinical protocol using the GE extremity coil uses a lower spatial resolution with larger FOV and thicker slices. The lower signal uniformity in the phased array coil did not interfere with the anatomical evaluation of the knee.

The poor performance of the commercial knee coils in the evaluation of articular cartilage pathology has been hindering the detection of early and even later osteoarthritic changes in cartilage [3]. The lack of adequate S/N in the acquired images even reflects in the results of studies of the MR appearance of normal articular cartilage. The use of this improved coil design could advance both the clinical and experimental articular cartilage research.

References