Birdcage Array for Lower Extremity Angiography

R. Brown[1], E. Reid[2], A. Mareyam[2], H. Ersoy[1], M. R. Prince[1], Y. Wang[1]

[1]Radiology, Weill Medical College of Cornell University, New York, New York, United States, [2]MR Research Center, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania, United States

Introduction: An 8-channel, receive-only array for lower extremity imaging is introduced. The main criteria in the design of this array were to obtain high SNR and homogeneity over a FOV long enough to image the full length of the legs. Bolus chase MRA with a long FOV necessitated further design considerations since time limitations prohibit lengthy hardware or software changes after contrast injection.

Methods: Due to their cylindrical geometry and high SNR and homogeneity, birdcage coils (1) are a natural choice for lower extremity imaging. However, magnetic coupling complicates this approach. We designed a birdcage array consisting of four receive-only low-pass coils to image the legs (Fig. 1). Each of the eight modes were individually tuned to 63.87MHz and capacitively matched to 50Ω while loaded with a cylindrical phantom doped with $CuSO_4$ and NaCl designed to approximate leg loading. The coils were decoupled from the body coil during excitation using multiple crossed-diode passive decoupling circuits. Bazooka baluns were used to transfer signal from the coils to the MR scanner and to reduce unsafe RF current leakage on the coax cable shield.

It is especially important to minimize the inductive coupling between coil elements in a birdcage array. Coupling in coil arrays is typically reduced through the use of low impedance preamplifiers which reduce current flow (2). This is a valuable method in certain surface coils where current can be substantially reduced by introducing a single high-impedance point. However, multiple rods and current paths make it is less suitable for birdcage arrays. Accordingly, in addition to standard preamplifier decoupling, we used the following techniques to isolate neighboring coils: inferior and superior coil sets were partially overlapped (3), adjacent coils were positioned such that their drivepoints were rotated by 0° or 90°, modes with parallel B_1 fields (x_1-x_2, y_1-y_2) were isolated using flux compensators. Modes that excited orthogonal B_1 fields (x_1-y_2, x_2-y_1) were inherently decoupled. Together, these decoupling methods were used to divide the legs into four separate FOVs which permitted the use of multiple coils with reduced dimensions and hence higher SNR. Note that rods with flux compensators had greater self inductance than standard rods and required more distributed capacitors to sufficiently reduce electric field effects.

The array was designed such that only one coil set (two coils, or four channels) was active at once (i.e. when the thigh coil set was active, the calf coil set was turned off and visa-versa). A switching circuit was constructed to control which coils were in use by providing appropriate DC bias to the coils. The switch also served to properly route RF signals from each mode to independent receivers. S_{21} measurements showed that the switch added only a small insertion loss of <0.3dB.

Experiments were performed on a 1.5T MR scanner (Signa CV/i, GE Medical Systems). Two volunteers gave written consent for this study. First, time-resolved 2D projection MRA of the thighs was performed after a 6mL gadolinium (Gd) injection and bolus arrival time in the thigh was noted. Then, a two-station 3D bolus chase of the leg was performed following injection of 34mL Gd at 1.5mL/s. During the exam, thigh compression was applied bilaterally (50mmHg) using a blood pressure cuff to suppress venous flow (4).

Results: Figure 2 shows time-resolved 2D projection MRA images which depict the filling of the femoral arteries and high order arterial branches. The visualization of arteries from the upper thigh to the popliteal trifurcation demonstrates the coverage of the thigh coil set. Figure 3 shows an image from the 3D bolus chase sequence. Here, major arteries as well as their high order branches are delineated with excellent clarity without the use of any background subtraction methods. However, soft tissue and bone were trimmed from the image. In conclusion, we demonstrate that magnetically decoupled birdcage coils can be utilized in a phased-array arrangement for independent imaging of each extremity. In this way, the coils provided uniform signal reception, quadrature noise reduction, and were tailored to the anatomy for greater sensitivity. By adapting this design for use on a system with more receiver channels, the length of each coil element could be reduced which would further improve SNR.

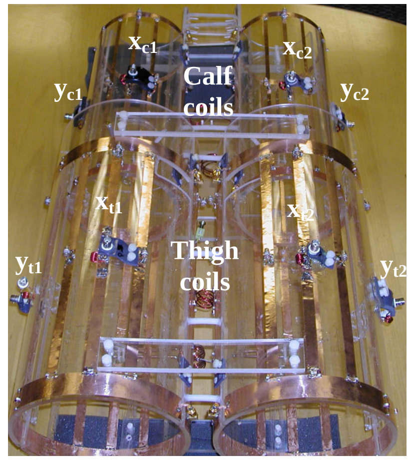

Fig. 1. Photograph of the 8-channel birdcage array. One coil was used to cover each thigh and calf. The length of the array was 70cm, and the coil diameters were 20.3cm for the thigh coils and 15.2cm for the calf coils.

Fig. 3. Two-station bolus chase MRA image using a spoiled gradient echo sequence with TR/TE/α=5.3ms/1.2ms/30°, thickness=3mm, 512x192 matrix (thigh), 512x256 matrix (calf), FOV=42cm (thigh), FOV=44cm (calf), NEX=1, and receiver bandwidth= 62.5kHz.

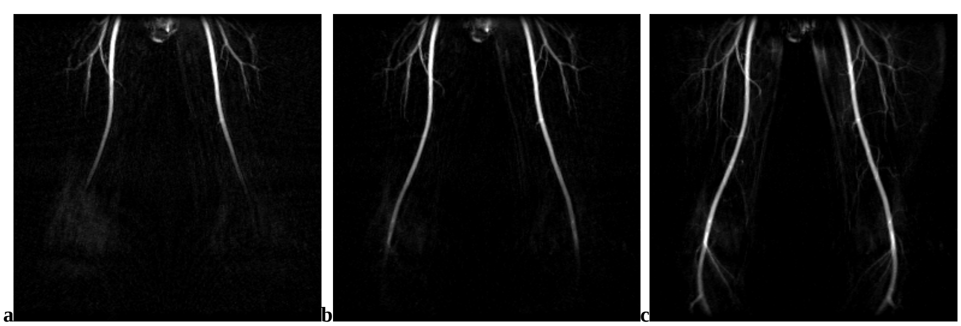

Fig. 2. Thigh images from a time-resolved 2D projection MRA sequence. Frames acquired approximately **a**) 22s, **b**) 26s, and **c**) 30s after Gd injection. Images obtained using a gradient echo sequence with TE=1.8ms, TR=8.4ms, α=60°, volume thickness=60mm, 256x256 matrix, FOV=42cm, NEX=1, and bandwidth=16kHz.

References: 1.Hayes CE, et al. J Magn Reson 1985;63:622. 3.Misic G, Reid E. US patent 1993;5,258,717.
2.Roemer PB, et al. MRM 1990;16:192. 4.Zhang, et al. AJR 2004;183:1041.