Mouse cardiac MRI using open birdcage coil – Comparison with single loop and body coils

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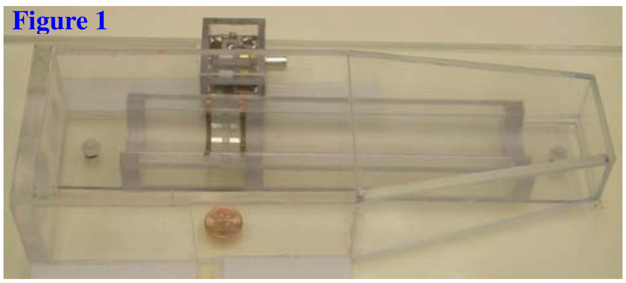
Introduction: The mouse is an extremely important model for studying cardiac disease due to the plethora of transgenic and knock-out/in animals which have been produced. In order to fully appreciate the perturbations generated in these models, physiologically relevant MRI paradigms need to be designed. Mouse cardiac MRI is challenging mainly due to low tissue mass (~120 mg) and high heart rates (~500-700 bpm). Surface coils are often used because of the location of heart near the chest wall. A surface coil is often constructed from a single loop which, although simple in design and application, does suffer from poor B_1 field uniformity. Volume coils have also been used and although do not suffer from B_1 field inhomogeneity, are not optimized for localized cardiac detection and do not provide easy access to the animal. Therefore, to maintain simplicity of application, high B_1 field uniformity, and accessibility to the animal, we designed and constructed a low pass open birdcage coil for mouse cardiac MRI. The quality of simple loop surface coil, closed birdcage and open birdcage coil was compared. To complement the open birdcage coil design, a chamber was constructed to maintain the mouse in a good physiological state, obtain clear ECG signals for image gating and isolate the animal from all coil components (Figure 1).

Figure 1



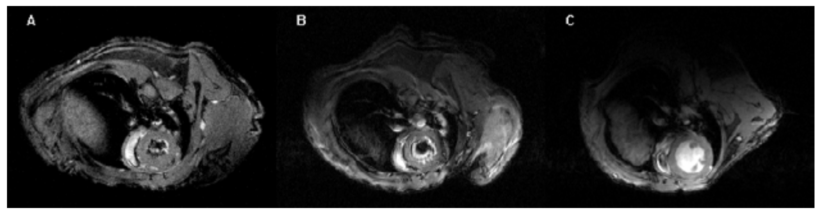


Figure 2. Mouse cardiac images acquired at 4.7T. Images were obtained from a (a) Body coil, (b) Single loop coil, and (c) Open birdcage coil, respectively.

Materials and Methods: ***Physiological Imaging Chamber:*** A clear plexiglass chamber was built to incorporate the open birdcage coil, animal holder, and access ports for ventilation, ECG, temperature and infusion lines. This chamber provides consistent airflow necessary for warming without requiring the animal to be wrapped or covered. This also allows for consistent and clear ECG signals for gating. ***Open Birdcage:*** A six leg low pass open birdcage coil (Figure 1) was constructed on a polycarbonate tube with outer diameter 2.6 cm and inner diameter 2.3 cm which was cut in half. The coil width matched the curvature of the tubing at 4 cm long and the length was designed to match the mouse chest at 2 cm in length. In order to reduce the number of solder points, the leads of capacitors (total 1.8 cm long) served as the legs of the birdcage coil and these were attached to the end-ring which was made from copper tape cut into 0.25 cm width. ***Single Loop:*** The single loop surface coil had a similar size and shape as the open birdcage coil but was constructed from 0.25 cm wide copper tape which was arranged into a 4×2 cm rectangle. ***Closed Birdcage:*** A standard eight leg low pass birdcage coil (3.8×3.8 cm) was used. **Experimental Setup:** Mice were anesthetized with isoflurane and a SA physiological monitoring system (Brooklyn, NY) was implemented to acquire ECG signals for gating and to maintain body temperature at 38°C. Image acquisition was triggered 10 ms following the cardiac R wave. All experiments were conducted on a Bruker 4.7 Tesla animal scanner with a 20 G/cm gradient set. Conventional gradient images were acquired using all coils (TR/TE = 16/4.9 ms, slice thickness = 0.5 mm, FOV = 3.0 cm, array size = 256×256, flip angle = 15º, NEX = 4). Image signal to noise ratio (SNR) comparisons were determined using comparable ventricular wall ROIs.

Results: The SNR obtained from the ventricular wall was **10** for the closed birdcage coil, **23** for the single loop coil, and **32** for the open birdcage coil. Representative images are shown in Figure 2. The open birdcage coil design for mouse cardiac MRI results in high ventricular wall SNR surpassing that obtained with either the single loop or closed birdcage coil design. When combined with an optimized physiological chamber, this coil design provides excellent mouse cardiac MR images critical for studying transgenic mice.

Discussion: The open birdcage coil has all the ease of use advantages of a single loop coil but with a higher signal to noise ratio and greater B_1 field uniformity. The volume coil with the same size curvature of surface coil can not accommodate the mouse and therefore, a larger sized coil would have to be used. This would reduce the filling factor with a decreased signal to noise ratio as shown in this study. Therefore, the open birdcage coil is a good choice for imaging organs like the heart that are close to the skin. When interfaced with a physiological chamber, high quality and functional cardiac images can be obtained from the mouse.