# Chronic Exertional Compartment Syndrome of the Lower Extremities: Screening with MRI using a Novel Dual Birdcage Coil and In-Scanner Exercise Protocol

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**Introduction:** Chronic Exertional Compartment Syndrome (CECS) is a complex problem primarily affecting young female athletes. Patients experience debilitating pain during physical activity, most commonly in the anterior compartment of the lower leg. Although the etiology of CECS is not completely understood, it is felt to involve increased intracompartmental pressure resulting in ischemia. The gold standard diagnostic test, which is invasive and painful, involves the intramuscular placement of needles at rest and during exercise to measure pressure in the affected compartment. MRI has been used to assess muscle at rest and during exercise by qualitatively and quantitatively measuring T2 changes associated with muscle activity. Applying this concept to the evaluation of CECS, however, has been technically challenging due to inadequate SNR when using the body coil, inadequate uniformity when using surface coils, and misregistration due to patient motion. We present a novel coil design to maximize SNR and image uniformity, a patient positioning device to minimize registration errors and enable isometric dorsi and plantar flexion in the magnet, and an imaging protocol to reduce scan time. Our early *in vivo* results show high sensitivity and specificity for the diagnosis of CECS.

**Materials and Methods:** Imaging studies were performed with a pair of adjacent quadrature transmit-receive birdcage coils measuring 19 cm in diameter and length. The coils were tuned and driven in a complimentary orientation to promote balanced coupling, loading and sensitivity (Figure 1). Proper coil performance was validated with phantom studies and then compared to the body coil and a receive-only torso phased array (SE TR/TE 400/20, 256x192, FOV 40 cm, 3 mm slice, 1 NEX). Patients and subjects were positioned with their calves in the coils, and their feet strapped to a rigid foot plate to allow repeated isometric plantar and dorsiflexion without leaving the magnet bore. Subjects were scanned at 1.5T using a T2W SE sequence (TR/TE 2000/80 ms, 256x128, FOV 40 cm, 10 mm slice, 0.75 NEX, ½ phase FOV). Images were acquired twice at each of the following phases: rest, isometric dorsiflexion, recovery, isometric plantar flexion and recovery. Ratio images of T2 signal intensity to baseline were calculated after thresholding, smoothing and re-registering the images from each acquisition. 8 normal subjects were compared to 17 patients with clinical symptoms suggesting CECS.

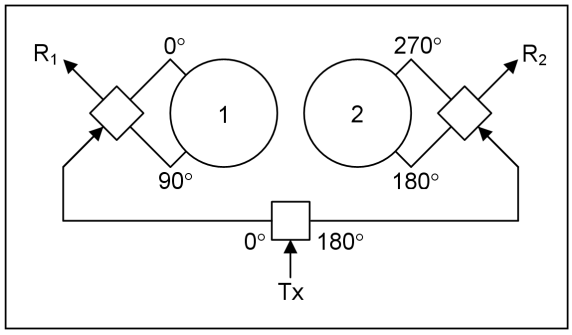


**Figure 1** – A schematic illustrating the electrical configuration employed to transmit and receive RF energy with the dual birdcage coil.

**Results:** Phantom studies show the paired birdcage coils exhibit 6 times the SNR of the body coil and 3 times the uniformity of the phased array. *In vivo* images were equally improved (Figure 2). Our initial results show that, of the 17 patients scanned, those with CECS had higher average peak ratios of T2 signal intensity, $p<0.0005$ (Figure 3). ROC analysis demonstrates a diagnostic accuracy of 100% in the left leg, 96% in the right, and implies an optimal diagnostic threshold of 1.6. Decreased accuracy in the right leg is the result of a single outlier due to non-uniform intensity within the prescribed ROI, which includes the entire anterior compartment for consistency. Additionally, while some normal subjects managed to achieve a ratio of greater than 1.6, all achieved this ratio during the second dorsiflexion period. All subjects with CECS, however, reached their peak intensity in the first recovery period after the two dorsiflexion events, and exhibited a slower return to baseline values relative to normal subjects and patients without CECS. 8 patients underwent invasive compartment pressure measurements. Of these, 6 had positive MRI and pressure tests for CECS and were treated with fasciotomy. Two patients were referred for compartment pressure testing despite negative MRI exercise findings. In both cases, results of the pressure tests were negative, and the patients were later diagnosed with other conditions. The remaining patients had MRI exercise test results that were indistinguishable qualitatively and quantitatively from the normal controls and did not go on to invasive pressure testing.

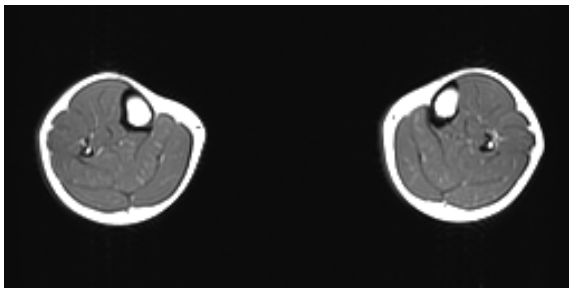

**Figure 2** – An axial T1W image of a CECS patient acquired with the dual birdcage coil, demonstrating high SNR and uniformity.

**Conclusions:** Our study shows improved uniformity and SNR using paired birdcage coils in phantom and *in vivo* studies of patients and normal subjects. Initial results using the paired birdcage coils and in-scanner exercise protocol show this test to have high sensitivity and specificity for the diagnosis of CECS in this group of selected patients with lower extremity pain with exercise. All patients with confirmed CECS had ratio measurements of 1.6.or greater. All patients reached their peak ratio in the first recovery period after the second dorsiflexion event and had a statistically significant increase in the ratio measurement between these two phases, supporting the observations of prior investigators that patients with CECS reach higher ratio of T2 signal intensity in the affected muscles and have a slower return to baseline values than normal subjects or patients with lower extremity pain of other etiology. Further study is required to validate our preliminary findings, but this work demonstrates the technical feasibility and reliability of an in-scanner isometric exercise protocol for screening patients with lower extremity pain for CECS.

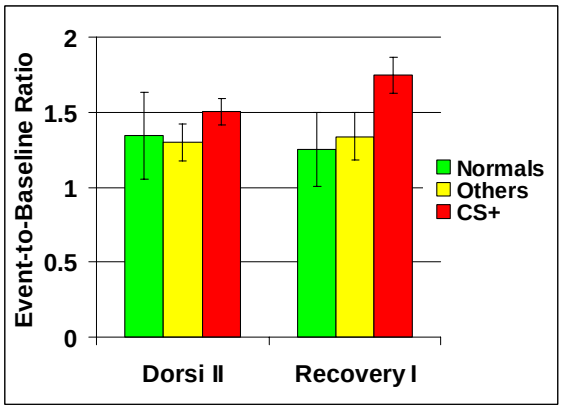


**Figure 3** – Left-right averages of average anterior compartment T2 intensity ratios for 3 groups at 2 imaging phases, clearly indicating a significant difference between CECS patients and other subjects.

**References:**

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