Improved Optic Nerve Imaging using a Collapsible Head Coil Design

R. Merrill[1], D. Parker[1], E. Minalga[1], L. Bell[1], J. Rose[2,3], and R. Hadley[1]
[1]Dept. of Radiology (UCAIR), Salt Lake City, UT, United States, [2]Neurovirology Laboratory VASLCHCS, [3]Brain Institute

Introduction: Many existing head coils are built using one-piece rigid cylindrical formers, to which phased arrays [1] are attached. While these non-adjustable coils provide high SNR when imaging patients with medium- to large-sized heads, performing advanced imaging techniques of the optic nerve (ON) has been problematic for patients with small-sized heads. Small heads tend to decrease the coil filling factor and increase the distance between the coil elements and sample (distance '*d* ', Fig. 1), resulting in a loss of SNR in the region from the orbits to the chiasm. The construction of an RF coil optimized for imaging the optic nerve was presented previously [2]. This coil features 28 channels arranged in a soccer-ball pattern [3] for full head coverage, and a collapsible former design (Fig. 2). The purpose of this work was to image samples at various positions within the coil to quantitatively determine the relative SNR (rSNR) benefit of the collapsible helmet construction. The studies were performed on a Siemens 3T MRI scanner [Siemens Healthcare AG, Erlangen, Germany].

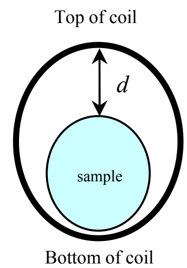

Figure 1. Axial view of a sample within a rigid, cylindrical head coil (with distance '*d*' defined).

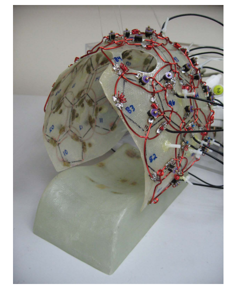

Figure 2. Optic Nerve (ON) coil with 28 channels and collapsible former design.

Methods: First, a cylindrical $NiCl_2$ phantom was imaged in a rigid Siemens 12-channel head coil at various vertical positions within the coil (d_{lower} = 60mm, d_{middle} = 25mm, d_{upper} = 2mm, see Fig. 3). Changing the coil-to-sample distance in this manner simulated the insertion of patients with various head sizes into the coil. Next, a normal volunteer was imaged in both the Siemens 12-channel coil and the 28-channel ON coil (Fig. 4). For each coil, the volunteer was placed in two different locations within the coil (Siemens coil: d_{lower} = 5cm, d_{upper} = 1cm; ON coil: d_{lower} = 2cm, d_{upper} = 0cm).

Results: In the Siemens coil phantom study (Fig. 3), an rSNR difference of 62% was observed between the two extreme lower/upper positions using a region of interest (ROI) that approximated the position of the orbits within the head; a difference of 22% was observed between the lower and middle positions. The volunteer study (Fig. 4) exhibited an rSNR improvement of 28% at the orbits when the ON coil was positioned in the lower vs. upper positions. Similarly, the Siemens coil exhibited an rSNR improvement of 32% between these two positions.

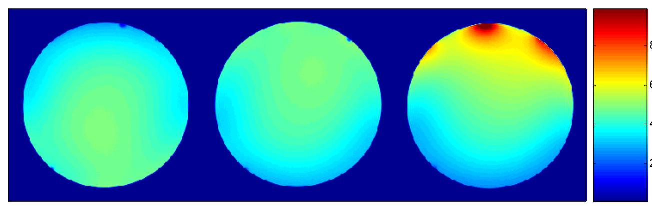

Figure 3. SNR plot of an axial slice through a cylindrical phantom placed in various locations within the Siemens 12-channel coil.

Discussion: While the collapsible design offers improved rSNR at the orbits and chiasm, significant imaging 'holes' can be observed in the regions surrounding the joint between the upper and lower formers where there is a gap in the coil overlap pattern (see Fig. 4). For ON imaging, high rSNR at the orbits and chiasm was of higher priority than uniform full-head imaging. The tight-fitting fiberglass former used in the ON coil was found to conform well to most patients, but can be less comfortable for patients with tendencies toward claustrophobia. For the variety of differently-sized heads that have been imaged in the ON coil for volunteer and clinical scans, the coil-to-sample distance remained consistently at *d* = 0cm. As an alternative to the collapsible design, achieving a small coil-to-sample distance in rigid coils may be possible by adding more padding to the bottom of the coil, forcing the face up near the top elements. However, a benefit of the collapsible coil design is that the placement of the coil on the patient is facilitated: rather than requiring the patient to 'wiggle' into the rigid coil, the patient can simply lie on the MRI table as the mask former is lowered into place.

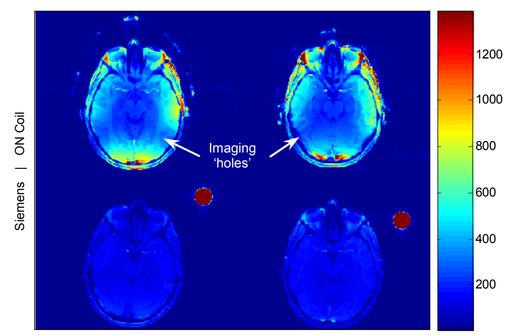

Figure 4. SNR plot of a normal volunteer placed in various locations within the ON coil and Siemens coil (large dot = small reference phantom; phantom placement remained constant during Siemens coil scans).

Conclusions: High-SNR imaging of the ON has typically been limited by the large distances between the coil elements and the orbits of the patient. Modern imaging techniques, such as high-resolution DTI and fiber tracking, cannot afford the loss of SNR resulting from a low filling factor. This study demonstrates that the collapsible feature of the ON coil is a key improvement in head coil design when performing such studies. Not only does the ON coil provide significant rSNR improvement along the length of the optic nerve from the orbits to the chiasm, but this improvement can be maintained for various sizes of heads. Numerous (15+) volunteer and clinical studies demonstrate that the optic nerve can be visualized using 3T MRI with advanced imaging coils, providing improved care for optic neuritis patients.

References:

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