Development of a Receiver Coil Array for 2D Accelerated Imaging of the Complete Neurovascular System

P. M. Mostardi[1], E. G. Stinson[1], T. C. Hulshizer[1], P. J. Rossman[1], and S. J. Riederer[1]
[1]MR Research Laboratory, Mayo Clinic, Rochester, MN, United States

Introduction Two-dimensional accelerated imaging [1] with acceleration factors as high as R = 8 has been applied successfully in contrast-enhanced MR angiography (CE-MRA) of the brain [2, 3] and calves [4]. A key element of this implementation has been the use of multi-element receiver coils which are designed for the targeted anatomic region. Multi-element coils for brain MRI are available on commercial MRI systems and can be used for accelerated CE-MRA of the brain vasculature. For example, on the commercial MRI systems at our institution the eight-channel birdcage-like brain coil (8HRBRAIN, Invivo Corporation, Gainesville Fl) can be used for R ≤ 8 2D SENSE brain CE-MRA. However, rather than be limited to the brain, a complete neurovascular exam also includes evaluation of the cervical carotid and vertebral arteries, and the aortic arch and great vessel origins. Another clinically available coil, the neurovascular coil array (NVA), is comprised of eight elements (five in the head region and three about the neck and upper torso). Although this provides expanded coverage to the neck and thorax, the limited number of elements in those areas limits the level of acceleration allowed. Thus, neither the 8HRBRAIN nor the NVA coils nor, to our knowledge, any other coil array allows high 2D acceleration over this extended region. The purpose of this work was to develop a multi-element receiver coil array for neurovascular imaging that has high SNR and the capability for high (R = 4 to 8) 2D SENSE acceleration from the head through the upper torso. Specifically, we hypothesized that a composite array composed of the 8HRBRAIN and an additional modular (8-12 channel) neck/torso array would provide the targeted performance.

Methods ***Coil Design.*** The performance specifications for the composite coil array were (i) S/I coverage from the top of the head through the upper torso, (ii) 2x increased signal at the level of the carotid bifurcation compared to the NVA, and (iii) capability for R = 4 to 8 2D SENSE acceleration, with the acceleration directions being A/P and L/R. The design specifications for the new neck/torso portion of the composite coil were: (i) use in conjunction with 8HRBRAIN; (ii) a maximum of 16 elements for the neck/torso array (due to hardware limitations on our scanner), and (iii) a close-fitting circumferential placement for improved parallel imaging performance in the neck. A circumferential placement has previously been shown to be effective for 2D acceleration within the transverse plane [2, 4]. The design process included several steps. First, for a close, circumferential fit around the neck and good coverage in the upper torso, a linear array of elements with longer elements anteriorly was conceived. Second, the appropriate element numbers and sizes were experimentally determined to be three circular/octagonal elements 7.2 cm in diameter on each side of the neck with two longer rectangular/octagonal elements (6.2 x 18.0 cm^2) on the anterior neck. Third, the optimal coil overlap was found by minimizing mutual inductance. The resultant array is shown in Fig. 1A. ***Phantom Studies.*** SNR comparison with the clinical NVA was performed using an axial GRE acquisition. Parallel imaging performance was assessed with a 4x SENSE accelerated CAPR [2] acquisition. ***In Vivo Studies.*** Volunteer studies were performed with an R = 4 2D SENSE-accelerated 3D time-resolved CAPR acquisition using 2 mL Multihance that serves as a timing scan for a subsequent carotid angiogram and intracranial venogram. Three volunteer studies have been performed using this coil. The neck array was wrapped around the subject's neck from the anterior side and secured while the patient was lying in the 8HRBRAIN cradle. The head coil was then slid into place (Fig. 1B). ***Analysis.*** SNR ROI measurements were made and g factor maps calculated for phantom and in vivo studies.

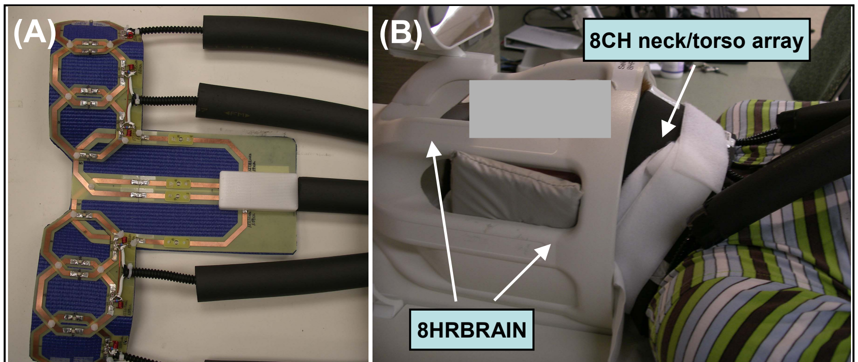

Figure 1: (A) Neck/torso coil array. (B) Setup of composite coil on a subject.

Results In phantom studies the newly designed coil (8CH head + 8CH neck array) showed on average 70% higher SNR and 13% lower median g factors (1.07 vs. 1.21) than the NVA coil throughout the desired S/I FOV. In volunteer studies the new coil showed good performance. There was no artifact from coupling of the neck/torso array with 8HRBRAIN nor residual SENSE aliasing. In the low-dose timing scan, the new array (Fig. 2E-H) showed higher SNR and significantly less noise at the level of the carotid bifurcation (Fig. 2 C,G arrows and D,H) than the clinical neurovascular array (Fig. 2A-D). However, there was residual signal drop-off inferiorly giving inadequate coverage of the aortic arch (Fig. 2E, arrow). In the high spatial resolution carotid angiogram there was high signal through the carotids and intracranial vasculature. The intracranial venogram shows high quality, similar to that of the 8CH head coil alone.

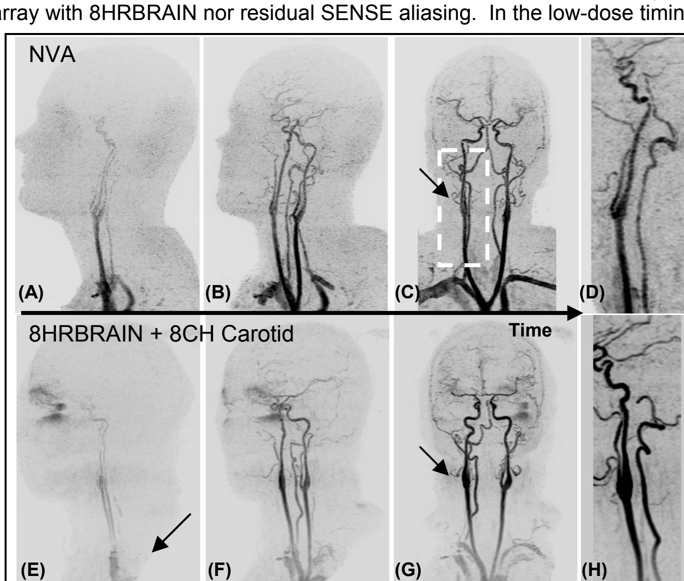

Figure 2: Consecutive rotational MIPs from 4x CAPR low-dose time-resolved scan with NVA (A-C) and new coil array (E-G). Zoomed oblique MIPs (D,H) from area in white box from time frames C,G respectively.

Conclusion We have shown that the newly developed 8CH neck/torso array used in combination with the clinical 8HRBRAIN head array provides high quality accelerated imaging over an extended S/I field of view. The combination offers improved performance over the current clinical NVA in the region from the carotid arteries through the intracranial vasculature. However, the current generation of the array does not adequately cover the aortic arch. Design of the next generation coil is in progress and includes more and longer anterior elements to help extend coil coverage inferiorly. In future work the 8HRBRAIN may be replaced with a coil with more elements, allowing for higher parallel imaging factors in the neurovascular exam.

References [1] Weiger, Magma 2002 [2] Haider, MRM 2008 [3] Hadizadeh, Radiol 2008 [4] Haider, Radiol 2009