An adjustable 8-channel coil array for MRI of the human wrist

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Introduction

The human wrist comprises a large number of subtle but clinically important bone, cartilage, muscle and nerve structures in a small volume. Revealing these structures requires very high spatial resolution, which can only be achieved with highest signal-to-noise ratio (SNR) efficiency. For maximizing the SNR it is essential to use multiple small, independent receiver coils that fit the anatomy very closely. However, fitting a coil array to the wrist is difficult due to the complex shape and variable size of this anatomy. In addition, fitting receiver coils tightly is challenging with respect to handling and patient comfort. In response to these issues we have developed an 8-element coil array that adjusts to each individual wrist.

Materials and Methods

The small dimensions of the average human wrist and the number of coil elements determine the physical size of each coil element. The target volume for wrist imaging is approximately a truncated cone. The circumference of the wrist varies roughly between 15 cm and 20 cm, whereas the circumference of the hand including the thumb is about 8 cm larger. Based on these numbers a conical array was composed of 8 trapezoidal elements of 2.3/3.3 × 7cm. Individual deviations from this geometry are accommodated by two measures. First, the coil loops were made of 0.4 mm highly flexible FR4 circuit board and are pressed against the wrist by separate, elastic polycarbonate “fingers”. Second, the 8 coils were mounted on an acrylic frame that permits opening and closing the coil cone as a whole by sliding one of the support plates towards the forearm (Fig. 1). Each coil element is actively detuned and connected to a high-impedance, low-noise preamplifier through a matching network. All components are placed on a narrow circuit board to permit the desired octagonal arrangement. The boards and cables extend away from the body for patient comfort and safety.

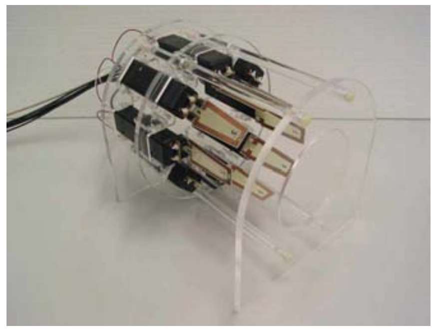

Fig. 1a: Wrist array in the ‘open’ state. The total length is 25 cm.

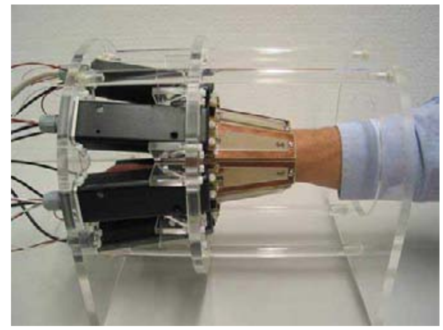

Fig. 1b: The array is fitted to the individual wrist by sliding the acrylic plate in the middle towards the forearm.

Results

The array was operated on a 3T whole-body system (Achieva, Philips Medical Systems, Best, NL). A first series of experiments aimed to optimize the matching networks with respect to overall SNR. This optimization is governed by the competing goals of isolating the coils [1] and minimizing the noise figure of the preamplifiers [2]. The maximum-SNR settings were identified by imaging of a phantom, stepping through a range of matching configurations. The highest SNR was accomplished with incomplete isolation (Fig.2), supporting earlier suggestions that moderate coupling does not necessarily impair the array SNR [3,4]. Figure 3 shows sample transverse images of different-sized wrists from two volunteers. In these scans a very high in-plane resolution of 162 x 162 µm was achieved in only 7 minutes of scan time.

Conclusion

The described wrist array achieves consistently excellent SNR by adjusting to each individual wrist’s shape and size. The highest SNR yield was obtained with deliberate residual coupling, indicating that the trade-offs involved in preamplifier matching deserve further study. The new array enables spatial resolutions well beyond current clinical standards. This perspective, combined with easy handling and patient comfort make it a promising design for clinical routine.

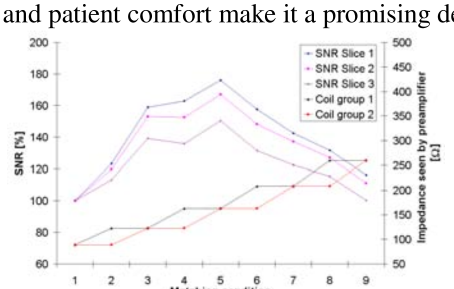

Fig. 2: Maximum SNR was achieved by matching each coil to 160 Ω at the preamplifier input, maximizing its noise figure.

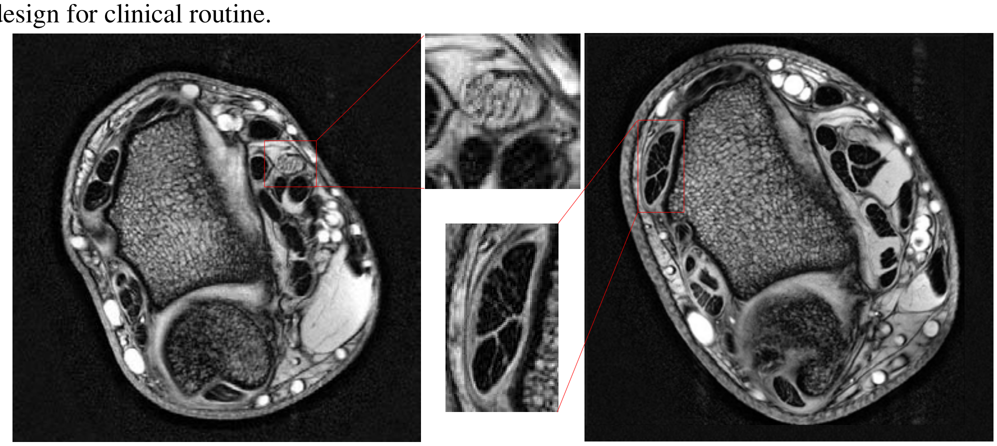

Fig. 3: Transverse wrist images from two different volunteers. Gradient echo, matrix=400x400, FOV=65 mm, 8 slices of 4 mm, TR= 132 ms, TE=8.3 ms, resolution=162x162µm^2, NSA=8, scan time=7 min. The enlarged details show individual fascicles of the median nerve and the internal structure of a tendon.

References 1. Roemer, P.B. MRM 16 p192 (1990) 2. Leussler, C. Proc. 11th ISMRM p2370 (2003) 3.Ohliger, M. MRM 52 p628 (2004) 4. Pruessmann, K. Proc. 10th ISMRM p196 (2002)

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