Specific Coil Design for SENSE: A Six-Element Cardiac Array

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Introduction

In MR imaging receiver arrays are usually used - and thus designed - to increase SNR (1). With the advent of imaging techniques utilizing receiver arrays for faster imaging new design criteria came along, e.g. for SMASH (2). Unlike the latter, sensitivity encoding (SENSE) (3) in principle deals with arbitrary coil sensitivities. Therefore, it is possible to minimize the inherent local noise enhancement by optimal choice of coil shapes and positions. Noise enhancement is described by the local geometry factor G that allows for a priori noise estimations. Conventional coil arrays usually show large geometry factors in the center (see Fig. 1c, left; max: 5.1) where overall sensitivity is relatively weak anyway (Fig. 1b, left). In this work we describe the design of a SENSE specific coil array for cardiac imaging taking into account the geometrical factor and compare it with a conventional one.

Methods and Materials

SENSE utilizes spatial information contained in the coil sensitivities of a receiver array for signal localization. This allows to reduce scan time by increasing the distance of lines in *k*-space, say, by a factor of R. The relation of local noise levels N for full and reduced Fourier encoding is

$$N_{reduced} = \sqrt{R} \cdot G \cdot N_{full}$$

The local geometry factor G describes the noise enhancement determined by the sensitivity relations. For a priori noise estimations simulations were based on Biot-Savart sensitivities similar to (4) but including noise levels and G. Noise maps showing N_{full}, G, and $N_{reduced}$ were extracted from phantom experiments. Cardiac SENSE images were acquired with a gradient echo sequence. All experiments were performed at 1.5T on a Philips Gyroscan ACS-NT15 equipped with six independent receiver channels. A coil design was realized consisting of six individual elements connected to a combiner box. The individual coil elements were built using preamplifiers and electronics similar to those described in (5).

Results

The simulation of a transverse slice for six channels and SENSE reduction factor $R = 3$ suggested the array shown in Fig. 1a (right) with two circular elements (∅ = 20 cm, grey) and four rectangular elements (10 × 20 cm^2, black). It turned out to be an important design criterion that differently from conventional coil arrays adjacent elements should not be overlapped. The reason for that is the dominant role of the coil phases in SENSE reconstruction. The conventional cardiac coil is shown on the left (two circular + three rectangular elements 13 × 19 cm^2). The evaluation of the phantom experiments in Fig. 1b shows slightly worse basic noise for the SENSE coil. However, the much better geometry factor (Fig. 1c, right; center maximum: 2.3) results in a clear improvement of the final noise distribution (Fig. 1d). The in-vivo images (Fig. 1e) with less noise for the SENSE coil in the center confirm the phantom results. The coil was also used and evaluated for oblique cardiac imaging showing similar results.

Conclusion

The simulation-based design enabled the realization of a cardiac SENSE coil with improved noise characteristics. Even though the sensitivities are load-dependent, the results of simulations, phantom, and in-vivo experiments are in fair agreement.

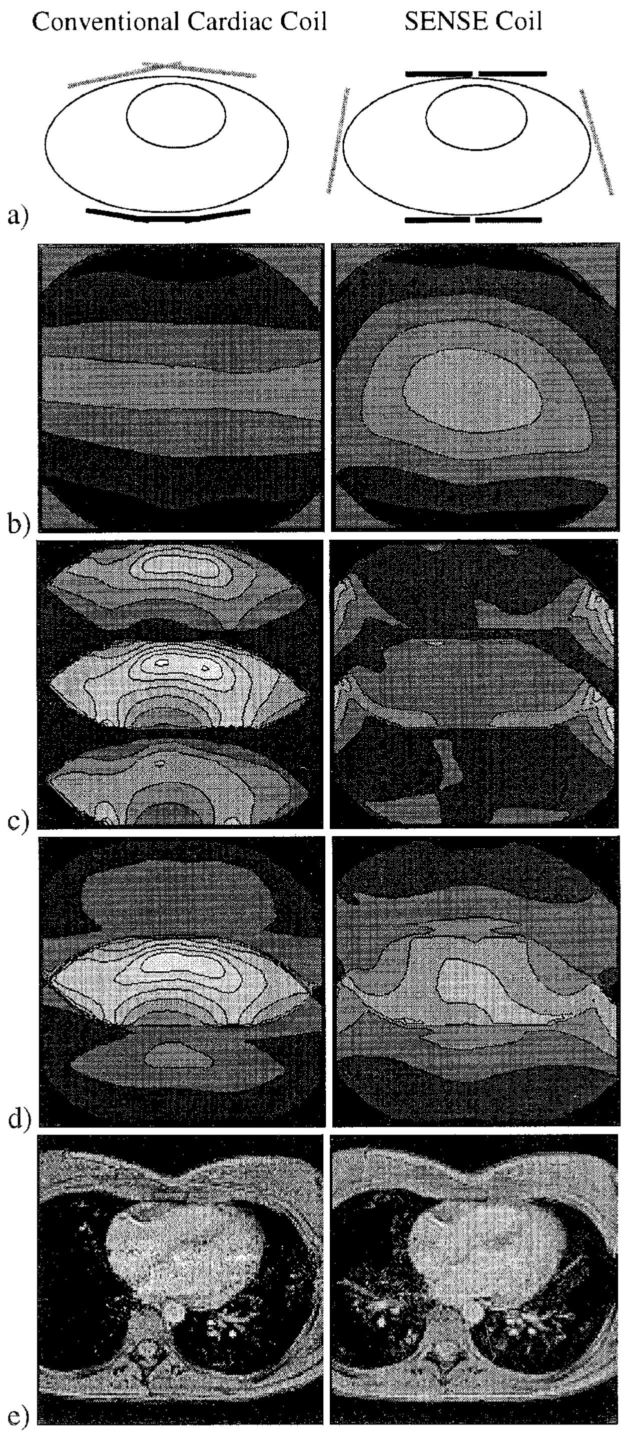

Fig. 1: Noise in SENSE for different coils with $R = 3$. a) Coil setup b) noise N_{full} (bright = strong noise) c) geometry factor G d) noise $N_{reduced}$ e) cardiac SENSE images.

References

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