TECHNICAL NOTE

Performance Assessment of Phased-Array Coil in Breast MR Imaging

Takayuki IKEDA*, Shuichi MONZAWA, Kyoko KOMOTO, Eiji Aso,
Yasuhiro SAITO, Tetsuo MAEDA, Takeshige SAKAMOTO, and Shuji ADACHI

*Department of Radiology, Hyogo Medical Center for Adults
13-70 Kitaoji-cho, Akashi-shi, Hyogo 673-8558, Japan*

(Received December 3, 2003; Accepted March 24, 2004)

Purpose: To compare the performance of the phased-array coil (PAC) with that of the single-loop coil (SLC) in magnetic resonance (MR) imaging of the breast.

Materials and Methods: MR imaging was performed with a 1.5T MR imager. A phantom study was performed with the right element of the two coils to obtain their signal-to-noise ratio (SNR). MR images of the breasts of 12 patients with breast lesions were obtained with the PAC and SLC, and these images were reviewed by five readers in a blind evaluation employing a scoring system for assessing overall image quality.

Results: In the phantom study, the SLC exhibited a SNR 1.82 times higher than that of the PAC at the center of the coil; however, the SLC exhibited an inhomogeneous sensitivity profile and its SNR varied with the distance from the center of the coil in the horizontal and vertical directions. In most of the 12 patients, the MR images obtained with the PAC showed more noise than did those obtained with the SLC, and the PAC obtained lower scores than the SLC in the assessment of overall image quality; however, the difference was significant ($p < 0.05$) only in coronal imaging. On the other hand, the uniformity of fat saturation in the MR images obtained with the PAC was judged to be significantly superior to that obtained with the SLC ($p < 0.05$).

Conclusion: Compared with the SLC, the PAC exhibited a lower SNR and was less advantageous at depicting the breast. However, the PAC provided more homogeneous fat saturation and might be useful for reducing artifacts.

Keywords: *magnetic resonance (MR) imaging, breast, coil*

Introduction

Surface coils are an essential part of magnetic resonance (MR) imaging. In general, the diameter of a surface coil is closely related to its signal-to-noise ratio (SNR); specifically, the smaller the diameter of the coil, the better its SNR. However, it has the disadvantage of a decreased scan range. The phased-array coil (PAC) is a technology that combines several coils and acquires their MR signals simultaneously. This technology provides a high SNR and an extended field-of-view (FOV).^{1,2} The PAC was put to practical use initially for MR imaging of the pelvis and abdomen; more recently, its scope of application has been expanded with the development of dedicated PACs for MR imaging of the breast and various other organs.

In our institution, a single-loop coil (SLC) and a PAC were used on two MR imagers for breast MR imaging. In daily practice, we often felt that the quality of the MR images obtained with the PAC did not always live up to their theoretical quality as compared with the images obtained with the SLC. We then conducted an experimental study with a phantom and assessed the MR images of patients in order to compare the performance of the PAC with that of the SLC in MR imaging of the breast.

Materials and Methods

Coil structure

The PAC and SLC dedicated to breast imaging were tested in the present study (Fig. 1). These two coils were commercially available models (GE Medical Systems, Milwaukee, WI, U.S.A.). To demonstrate the profiles of these two coils, we attempted to scan them with a multi-slice com-

*Corresponding author, Phone: +81-78-929-1151, Fax: +81-78-929-2380, E-mail: cby78280@pop01.odn.ne.jp

Fig. 1. Photographs depicting the SLC (a) and PAC (b) and transparent views of the SLC (c) and PAC (d) obtained by multi-slice CT. In the SLC, the unilateral element comprises one oval coil (arrow), while in the PAC, the unilateral element comprises paired oval coils (thick arrow).

puted-tomography (CT) scanner in order to create three-dimensional images of them. The images showed that the PAC and SLC had two elements, one each for the right and left breasts. In the PAC, the unilateral element comprised paired oval coils; in the SLC, the unilateral element comprised a single oval coil.

Data acquisition

All experiments were conducted with a superconducting 1.5T MR imager (Signa Twinspeed, GE Medical Systems, Milwaukee, WI, U.S.A.). A phantom study was performed to obtain SNRs meeting the standard of the National Electric Manufacturers Association (NEMA).³ A spherical phantom (10.8 cm in diameter) containing 0.1% NiCl₂ solution was used. Axial and coronal T₁-weighted MR images of the phantom were obtained with the right-side element of the two coils by means of a spin-echo sequence with a repetition time of 500 ms, an echo time of 9 ms, a received bandwidth of 31.25 kHz, a FOV of 20 × 20 cm, a slice thickness of 5 mm, a matrix of 256 × 256, and one excitation. The phantom was placed at the center of the right element (Fig. 2). Since the shapes of the two coils used were unique and different, the centers of the coils were defined as follows: in the horizontal direction and the direction of static magnetic field, the centers were set as the midpoint of the minor and major axes of the oval coil of the SLC and the posterior (chest-wall side) oval coil of the PAC. In the vertical direction, the centers were set as a site 5.4 cm anterior (nipple side) from this midpoint (Fig. 3). The phantom was scanned twice

Fig. 2. Photographs of the phantom experiment

Fig. 3. Illustrations showing the positions of the coil centers of the SLC (a, c) and the PAC (b, d), defined for convenient SNR measurement. Illustrations a and b show en-face views; c and d show profile views. A phantom was placed in the two coils and its center was set to the coil center.

sequentially with less than five minutes elapsed from the end of the first scan to the beginning of the second. The two sets of MR images acquired were subtracted to calculate the standard deviation within the measurement of the region of interest (ROI). Using an operator-defined square (15 × 15 pixels) ROI, T. I. measured SNRs at intervals of 1.5 cm on these images (Fig. 4).

Thirteen patients were enrolled in the study of *in vivo* MR images. These patients were referred to the Breast Medical Oncology Department of our institution for evaluation of focal right breast lesions suspected from X-ray mammographic and ultrasonographic examinations. Informed consent

Fig. 4. The SNR is measured with the use of a square-shaped (15×15 pixels) region of interest (large open square) at the coil center and intervals of 1.5 cm (small squares) in the phantom.

was obtained from the patients prior to the study. The SLC and the PAC were used in turn, and fat-saturated T_1 -weighted spin-echo MR images of the entire right breast were obtained with the patient in the prone position with the right-side element of the two coils and a repetition time of 500 ms, an echo time of 9 ms, a received bandwidth of 31.25 kHz, a FOV of 20×20 cm, a slice thickness of 5–9 mm, a slice gap of 1 mm, a matrix of 512×192 , and two excitations. Fat-saturated imaging was adopted for *in vivo* MR imaging on the basis of the report by Merchant et al. showing that imaging with the fat-saturated technique was useful for assessing breast disease.⁴ Since MR images of one patient were degraded by motion artifact, this patient was excluded; therefore, the study group comprised a total of 12 women (age range, 37–82 years; mean age, 58.3 years).

The MR images of the 12 patients were assessed independently by five readers (two radiologists [S.M. and T.M.] and three radiological technologists [K.K., E.A., and Y.S.]). Two sets of images obtained with the two coils were paired and displayed in two rows on films with identical display windows and at identical levels. The patient information and technical details—including imaging sequences, parameters and the name of the coil used—were masked. The readers were asked to grade the overall image quality, especially image noise and uniformity of fat saturation, and the depiction of breast tissue on a three-point scale: 1, unacceptable; 2, fair; and 3, excellent.

The mean scores for the two coils were calculated and analyzed with non-parametric statistical methods (Wilcoxon signed-rank test) for comparisons to obtain qualitative results. Differences were considered significant if two-tailed *p* values were less than 0.05.

Fig. 5. Changes in the SNR according to the distance from the imaging center in the static-magnetic-field (a), horizontal (b), and vertical directions (c)

Note: The SNR of the SLC is represented by the line with circles; that of the PAC is represented by the line with squares.

Results

As shown in Fig. 5, the SNR varies with the distance from the center of the coil. The SLC exhibited a higher SNR at the center than did the PAC at all measurement points; at the coil center, the SNR of the SLC was 1.82 times higher than that of the PAC. However, the sensitivity profile of the

Fig. 6. Coronal fat-saturated T_1 -weighted SE images obtained in a patient with the SLC (a, b) and PAC (c, d). Inhomogeneous fat saturation is noted in the MR images obtained with the SLC (arrows).

Fig. 7. Evaluation of overall image quality in coronal (a) and sagittal imaging (b)

SLC was inhomogeneous in the imaging area and its SNR varied with the distance from the coil center. SNR changes were large in the horizontal and vertical directions, and the SNR decreased especially in the outer and anterior (nipple-side) regions. SNR changes were relatively small in the direction of the static magnetic field. On the other hand, the PAC provided a uniform SNR in all three directions.

Figure 6 shows MR images obtained with the two coils in a patient with breast lesions. For most of the 12 patients, MR images obtained with the PAC exhibited more noise than those obtained with the SLC, and the PAC revealed lower scores than did the SLC in the assessment of overall image quality; however, the difference was significant only for

Fig. 8. Evaluation of the uniformity of fat saturation in coronal (a) and sagittal imaging (b)

coronal imaging (Fig. 7). Nonetheless, the uniformity of fat saturation in MR images obtained with the PAC was judged to be significantly superior to that obtained with the SLC ($p < 0.05$; Fig. 8).

Discussion

In recent years, breast-conserving therapy, which involves partial mastectomy and irradiation, has been widely adopted for the treatment of breast cancer. This therapy is usually indicated for small and localized tumors and requires an accurate evaluation of the extent of the disease for surgical planning in order to reduce postoperative in-breast recurrence and ensure good cosmetic results. Breast MR imaging now plays an important role in breast-conserving therapy because of its superior ability to depict tumor mass as well as peritumoral infiltration such as extensive intraductal components.⁵

Successful MR imaging of breast cancer requires high spatial resolution and good image uniformity. PAC technology allows for simultaneous acquisition and subsequent compiling of data from a multitude of closely positioned receiving coils; moreover, it offers the SNR and resolution of a small surface coil over a FOV normally associated with body coil imaging with no increase in imaging time.¹ However, the results of our phantom experiment and patient study did not live up to the promise of this approach. Although Konyer et al. reported that the four-coil arrays provided a superior SNR,⁶ their comparison of the coils was conducted on only one subject; therefore, individual variation could not be excluded.

As shown in Fig. 5, the sensitivity profile for the SLC was inhomogeneous in the imaging area, and the SNR fell especially in the outer and anterior (nipple-side) regions. With the SLC, an oval coil is placed obliquely along the chest wall, and the distance between the coil circuit and breast tissue is increased on the outside. As a result, the signal

from the tissue is decreased. In contrast, the PAC showed a more homogeneous SNR than did the SLC. With the PAC, the unilateral element comprises paired anterior and posterior oval coils. The posterior oval coil is placed obliquely, in a manner similar to that used for the SLC. The anterior oval coil is placed anteriorly in the nipple direction, receives the signal from the anterior and outside region of breast tissue, and covers the 'blind' area of the posterior oval coil. However, the SLC revealed a higher SNR than did the PAC at all measurement points, even in the outer and anterior portions. The reason for this was unclear, and our system might require tuning. Further testing at other institutions might be necessary.

In the patient study, the PAC showed more homogeneous fat saturation in MR images than did the SLC. Presumably, with the PAC providing homogeneous sensitivity over the imaging area, the active shimming system worked well and created a uniform static magnetic field where the fat saturation pulse could act on the breast tissue homogeneously and effectively. This result might indicate that the PAC might be useful for reducing artifacts caused by incomplete saturation of the fat signal.

In conclusion, compared with the SLC, the PAC showed a lower SNR and revealed disadvantages in depicting the breast. However, the PAC provided more homogeneous fat saturation and might be useful for reducing artifacts.

Acknowledgments

We thank Mr. Shigeru Hibino (GE Yokokawa Medical Systems) for his technical suggestions. The authors also thank the radiologists and radiological technologists in the Department of Radiology of the Hyogo Medical Center for Adults.

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