Original Investigation

Contrast Enhancement in Breast Cancer and Background Mammary-Gland Tissue During the Super-Early Phase of Dynamic Breast Magnetic Resonance Imaging

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Rationale and Objectives: We aimed to compare the contrast enhancement between tumor and mammary-gland tissue to distinguish lesions in the super-early phase, during which minimal contrast media uptake is observed in mammary-gland tissue.

Materials and Methods: Dynamic magnetic resonance imaging, including the super-early phase with bolus tracking (BT) method (to determine the optimal imaging start time), was performed by using identical parameters to obtain transverse fat-suppressed T1-weighted images of both breasts. The percent enhancement (PE) and the contrast ratio (CR) indicators for tumor and mammary-gland tissue were assessed in each dynamic phase.

Results: The PE values of the tumor were 62.4% and 151.6%, and those of the mammary gland were 0.3% and 20.7% in the super-early and early phases, respectively. Therefore, virtually no background parenchymal enhancement was observed in the super-early phase. The variation in the PE values during the super-early phase was significantly smaller when the values were determined with the BT method ($P < .05$). The CR was highest in the early phase, and the CR in the super-early phase was lower than in the other phases. Early-phase PE and CR were significantly higher in invasive cancer cases than in noninvasive cancer cases ($P < .01$). A significant difference in the imaging start time was observed for the anatomic side factor by the BT method.

Conclusion: Background parenchymal enhancement almost never appeared in the super-early phase, but the CR was lower in the super-early phase than in the early phase. The BT method allowed for an optimal imaging start time for the super-early phase and yielded images with less deviation of contrast enhancement.

Key Words: Breast; magnetic resonance imaging; background parenchymal enhancement; breast cancer; mammary gland; contrast media.

INTRODUCTION

The increase in breast cancer-related morbidity has led to the widespread use of mammography, ultrasonography, and diagnostic imaging modalities in screenings and clinical examinations. Magnetic resonance imaging (MRI) is particularly considered useful for breast cancer examination. The American Cancer Society guidelines recommend MRI screening for patients with a lifetime breast cancer risk of >20% (1). High-field MRI facilitates higher resolution and faster imaging. When combined with the use of contrast media (CM), MRI can be used to detect breast cancer and examine its spread as well (2–4). The use of CM in MRI for breast cancer diagnosis is considered essential by many guidelines (5–7). In particular, dynamic MRI is recommended to differentiate benign from malignant tumors. For breast cancer, images are obtained at the early phase, wherein contrast enhancement peaks approximately 60–120 seconds after CM injection, and at the delay phase to confirm CM washout (5,7–9).

The menstrual cycle and other factors impact contrast enhancement in normal mammary-gland tissue (10–12). However, the number of contrast-enhanced breast MRI sessions that can be conducted daily is limited in some institutions; hence, it may not be possible to schedule examinations based on the menstrual cycle. In such cases, during conventional dynamic

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MRI, the CM is also taken up by mammary-gland tissue, sometimes even outside the menstrual cycle, which decreases the contrast with tumor tissue because of background parenchymal enhancement (BPE). Uematsu et al. reported that BPE negatively affects the detection, diagnosis, and staging of breast cancer (13,14). BPE is expected to be lower in the super-early phase because normal mammary-gland tissue becomes enhanced more slowly than tumors do (15). Based on this expectation, super-early-phase images would yield data that could assist in both the detection and diagnosis of breast cancer. Therefore, previous studies have attempted to improve the diagnostic capability of dynamic images by adding imaging during the super-early phase to the standard protocol (16,17).

In the present study, we focused on the contrast enhancement between breast cancer and normal mammary-gland tissue to investigate lesion depiction in invasive cancers at the super-early phase, during which minimal CM uptake is observed in mammary-gland tissue, that would yield good results in both the detection and diagnosis of breast cancer. As many cases of noninvasive cancer do not exhibit the classic patterns of contrast enhancement in invasive cancer (18,19), we separately analyzed invasive and non-invasive cancers. Moreover, we compared the superiority of two methods for initiating imaging: the bolus tracking (BT) method, wherein variations in contrast enhancement due to different sites of CM injection or circulatory dynamics can be reduced, and the fixed-time method. We also examined the differences in the imaging start times for the super-early phase based on the injection site by using the BT method.

MATERIALS AND METHODS

Subjects

The subjects who underwent imaging with the fixed-time and BT methods were selected retrospectively from among women who underwent MRI for suspected malignant breast tumors from August 2012 to December 2012. In our institute, the scheduling of MRI examinations does not consider the menstrual cycle. In total, 113 women (mean age, 53 years; range, 28–87 years) with 124 malignant tumors were selected; patients who had received chemotherapy (13 people, 15 tumors) were excluded. Imaging of the first 55 consecutive tumors was performed with the fixed-time method, including 40 invasive cancer cases, 12 non-invasive cancer cases, and 3 other pathology cases. Imaging of the remaining 69 tumors was performed with the BT method, including 54 invasive cancer cases, 10 non-invasive cancer cases, and 5 other pathology cases.

To investigate the differences in the imaging start time for the super-early phase based on the injection site with the BT method, we examined 234 patients who had undergone breast MRI from October 2012 to March 2013. Five patients with the slowest CM injection ratio were excluded. In these five patients, standard injection ratio was not achieved because a narrow needle was used or because the CM was injected into a fragile vein.

The ethics committee of our institution approved the analysis of these clinical images. All patients gave their informed consent to undergo breast MRI.

Imaging Sequences

All data acquisitions were performed by using a 3-Tesla MRI (Achieva 3.0T TX, Philips Healthcare, Amsterdam, The Netherlands) with a dedicated coil (Mammo Track SENSE Breast Coil 16 elements, Philips Healthcare, Amsterdam, The Netherlands). A power injector (Sonic Shot GX, Nemoto Kyorindo, Tokyo, Japan) was used to inject the CM. All images were obtained with the patient in the prone position, with both arms raised if possible. Transverse fat-suppressed gradient echo (GRE) three-dimensional (3D) T1-weighted images, called "e-Thrive," were obtained during four phases: precontrast, super-early phase, early phase, and delay phase. The dynamic phases followed fat-suppressed T2-weighted images and diffusion-weighted images. Table 1 describes the detailed imaging parameters for the fat-suppressed GRE 3D T1-weighted images. Fat suppression was performed through frequency-selective fat suppression (spectral attenuated with inversion recovery [SPAIR]; Philips Healthcare). We used an imaging protocol for high-resolution bilateral mammography recommended by the breast MRI guidelines (5–7,20), along with fat suppression.

Contrast Imaging Protocol

All the patients were injected with a gadolinium CM (0.1 mmol/kg body weight; 0.2 ml/kg) at 2 ml/s, followed by a 25-ml saline flush at the same injection rate. Meglumine gadopentetate (Magnevist, Bayer, Leverkusen, Germany) or gadodiamide hydrate (Omniscan, Daiichi-Sankyo, Tokyo, Japan) was randomly selected as the CM, whereas gadoteridol

TABLE 1. Acquisition Parameters of Fat-Suppressed GRE 3D T1-Weighted Images for Dynamic Breast MRI

Parameters	Values
Field of view (mm)	330 × 330
Matrix size	400 × 320
TR/TE (ms)	3.42/1.79
Flip angle (degree)	10
Echo train length	33
NEX	1
Slice thickness/gap (mm)	1.8/–0.9
Phase encoding order	Centric order
Acceleration factor; R–L/H–F	2/1
Half scan factor; R–L/H–F	0.675/0.8
Shimming	SmartExam Breast (Philips Healthcare, Amsterdam, The Netherlands)
Time per phase (s)	62

GRE, gradient echo; H–F, head-foot; MRI, magnetic resonance imaging; NEX, number of excitations; R–L, right-left; TE, echo time; TR, repetition time.