MAGNETIC RESONANCE IMAGING
CHARACTERISTICS OF PARAFFINOMAS AND SILICONOMAS AFTER MAMMOPLASTY

Jane Wang, Tiffany Ting-Fang Shih, Yiu-Wah Li, King-Jen Chang, and Hsin-Yi Huang

Background and Purpose: Breast paraffinomas and siliconomas are granulomas caused by tissue reaction to paraffin oil and silicone injection after mammoplasty. These granulomas usually present as multiple hard masses that mimic breast cancer. Mammography and sonography have only a limited role in differentiating these masses. Magnetic resonance (MR) imaging findings of these granulomas have rarely been reported. This study evaluated the MR imaging manifestations of these granulomas.

Materials and Methods: MR imaging, mammography, and sonography were used to examine 58 breasts in 29 women with breast lumps who had undergone mammoplasty with injections of paraffin oil (n = 8) or liquid silicone (n = 50). The protocol included T₁-weighted images (T₁WI), fat-suppressed (FS) T₂WI, post-contrast FS three-dimensional fast dynamic sequences, and FS T₁WI.

Results: Deep structures of the 58 breasts could not be clearly evaluated by sonography or mammography. Two types of MR imaging characteristics were identified: type I lesions were hypointense on T₂WI and type II lesions had mixed hypointense and hyperintense components on T₂WI. Both showed intermediate intensity on T₁WI and revealed no enhancement on post-contrast dynamic sequences and FS T₁WI. Type II lesions were seen only in siliconomas. Mastectomy was performed on seven breasts and paraffinomas or siliconomas were confirmed by pathology. When correlating MR images with pathology, hypointense lesions on T₂WI in both type I and II lesions were foreign body granulomas with fibrosis and calcification. Hyperintense lesions on T₂WI in type II were liquid silicone. A case of infiltrating ductal carcinoma was found in one breast in which MR imaging was successful in identifying the strongly enhanced solitary tumor from a background of type I lesions of paraffinomas preoperatively. Of the 51 breasts that did not receive surgery, no breast cancers were detected clinically or by follow-up imaging after a median of 27 months (19–54 mo).

Conclusions: Breast paraffinomas and siliconomas after mammoplasty have specific MR findings that are distinct from those of breast cancers. MR imaging is superior to sonography and mammography in the evaluation of breast paraffinomas and siliconomas.

The use of direct paraffin oil or liquid silicone injections for breast augmentation was commonplace in previous decades [1–3]. The procedures are no longer performed in Western countries due to marked complications such as hard masses in the breasts caused by granulomatous reactions, the occurrence of tissue necrosis, and lymphatic or hematogenous migration of paraffin or silicone materials [1–5]. However, such procedures were occasionally used in Taiwan even up to 10 years ago and the most commonly seen complications are granulomatous reactions in the breast termed paraffinomas or siliconomas [1–3]. Many patients suffer from these complications for prolonged periods, often for more than 10 or 20 years. In the literature, nearly all patients with paraffinomas or siliconomas of the breast present with the symptoms of hard breast...
masses bilaterally which are so hard that they can not be differentiated from breast cancers by palpation alone. In addition to this, extensive echogenic noise with a so-called snowstorm appearance or an associated hypoechoic mass, prominent acoustic shadowing that blocks the transmission of sound on sonography [2–4], and hyperdense patches or masses with streaky reticulated opacities causing bizarre architectural distortion, especially in the retroglanular region of the breast on mammography, are often seen in such patients [2–4]. Consequently, confident exclusion of underlying breast cancer is difficult [2–5], since the deeper features of the breast parenchyma cannot be clearly visualized by sonographic and mammographic images in such cases.

The role of magnetic resonance (MR) imaging of the breast in the evaluation of breast implant rupture and breast cancer is well established and has been shown to have high sensitivity [6–9]. On MR imaging, breast cancer typically shows as an ill-defined mass with hypointensity on T1-weighted images (T1WI), marked hyperintensity on T2WI with fast, and strong enhancement in post-contrast studies [10–14]. The superiority of breast MR imaging for the evaluation of breast paraffinomas has been previously described [2], but data are lacking for the use of MR imaging in the evaluation of breast siliconomas resulting from direct silicone injections. This study used MR imaging to evaluate 29 patients with direct paraffin or silicone injections who had developed complications of bilateral palpable breast masses. The MR imaging features of breasts with paraffinomas or siliconomas were investigated for their ability to differentiate them from breast neoplasms, and also to determine whether MR imaging is superior to sonography and mammography in differentiating granulomas and neoplastic lesions.

Materials and Methods

From May 1997 through April 2000, 29 female patients (aged between 31 and 74 yr; mean, 53.0 yr) with a history of bilateral direct breast injection of paraffin oil or liquid silicone were enrolled in the study. Among them, eight breasts in four patients underwent direct paraffin injections between 26 and 31 years prior to enrollment (mean, 27.1 yr), and 50 breasts in 25 patients underwent silicone injections between 8 and 31 years prior to enrollment (mean, 16.6 yr). Patients had suffered from bilateral hard breast masses for between 6 months and 6 years (mean, 28.4 mo) and there was associated breast deformity in six patients. For all patients, the possibility of breast neoplasm was difficult to exclude by physical examination alone.

Of the 29 patients, 26 underwent breast ultrasonography and 22 underwent mammography. All 29 patients underwent initial MR investigations in the prone position using a 1.5-Tesla MR scanner (GE, Signa, Milwaukee, WI, USA) and a phase-array dedicated breast coil (GE MRI Devices, Waukesha, WI, USA). The MR imaging protocol used in the study comprised sagittal or axial planes, spin echo (SE) T1WI (TR/TE 700–800 ms/18 ms; matrix 256 x 192; slice thickness 5 mm; interslice gap 1.5 mm) without fat suppression, and axial fast spin echo (FSE) T2WI (4,000–4,200/80; matrix 256 x 192; echo train length, 8; slice thickness 5 mm; interslice gap 1.5 mm) with fat suppression, followed by dynamic series which included fat-suppressed (FS) three-dimensional (3-D) axial fast spoiled gradient-recalled (FSPGR) images (26/2.3; flip angle 30º; matrix 256 x 128; slice thickness 4 mm without interslice gap) of bilateral whole breasts before intravenous contrast enhancement and then three cycles of repetitive FS 3-D FSPGR scans after intravenous infusion of 0.15 mmol/kg gadolinium diethylenetriamine pentaacetic acid (Gd-DTPA, Magnevist, Schering AG, Berlin, Germany). One set of FS 3-D FSPGR images took 90 to 100 seconds to complete and a total of about 5 minutes were needed for three cycles of post-contrast 3-D FSPGR. Post-contrast FS T1WI (800–900/18; matrix 256 x 192; slice thickness 5 mm; interslice gap 1.5 mm) delayed scans in sagittal or axial planes were performed. Only 48 breasts in 24 patients were imaged using pre-contrast and post-contrast dynamic 3-D FSPGR. Switching of phase-encoded and frequency-encoded gradients was used for 52 breasts in 26 patients to reduce misregistration artifacts caused by heartbeat.

The MRI findings of all breasts were analyzed according to the contours of the lesions, signal characteristics of the breast parenchyma and lesions on T1WI, FS T2WI, FS 3-D FSPGR, and enhancement patterns of post-contrast FS 3-D FSPGR and FS T1WI studies. During the clinical follow-up period, MR imaging was performed in one patient, mammograms were performed in three patients, and sonograms were performed in all patients. The image findings of the follow-up examinations were compared with the imaging manifestations on previous MR imaging.

Results

On MRI, the contours of breast paraffinomas were similar to those of siliconomas. They typically manifested as multiple well-defined variably sized round or ovoid nodules scattered through the breasts and were located in both deep and superficial regions. In addition, large associated bilateral amorphous patches were also
recognized and were principally located in the retroglandular portions of the breasts.

The breast parenchyma of all breasts showed intermediate signal intensity on T1WI, hyperintensity on FS T2WI and FS 3D FSPGR, and moderate enhancement on post-contrast dynamic FS 3D FSPGR and FS T1WI sequences.

The MR imaging findings in breast paraffinomas and siliconomas can be divided into two types according to their signal characteristics and enhancement pattern (Table). Type I lesions were markedly hypointense compared to breast parenchyma on FS T2WI (Fig. 1), while type II lesions showed mixed hypointense and hyperintense signals on FS T2WI (Fig. 2A–C). Both types of lesions revealed similar signal characteristics on the other pulse sequences and showed no definite enhancement in post-contrast studies. All eight breasts with paraffinomas exhibited the type I pattern. Of the 50 breasts with siliconomas, 41 (82%) showed the type I pattern, and nine (18%) revealed the type II pattern. All type II lesions occurred in breasts with siliconomas.

The corresponding mammographic and ultrasonographic findings typically showed bilateral paraffinomas or siliconomas, which obliterated the parenchymal details of the breasts (Fig. 2D).

Subcutaneous mastectomies were performed in six breasts and simple mastectomy was performed in one breast within 1 to 19 days (mean, 10 d) of the MR imaging studies. Paraffinomas were identified histopathologically in five breasts and siliconomas in two breasts (Fig. 3). Grossly, both the paraffinomas and siliconomas were elastic to firm in consistency and had numerous vacuoles of various sizes on the cut-surface. The vacuoles in paraffinomas contained translucent greasy materials compatible with paraffin oil, while the vacuoles in siliconomas had clear, pearly fluid indicative of liquid silicone. Areas of fat necrosis, fibrosis, and calcification were also discernible. On microscopic examination, the paraffin oil and liquid silicone were lost during processing, and both the paraffinomas and siliconomas exhibited vacuoles of various sizes surrounded by foamy histiocytes, a few lymphoplasma cells, and multinucleated foreign body giant cells (Fig. 3). Secondary changes including hemorrhage and fibrosis were also apparent. No evidence of malignancy was found in the six breasts that underwent subcutaneous mastectomy. When correlated with the MR imaging and histopathologic findings, the hypointense components in type I and type II lesions on T2WI corresponded to foreign body granulomas with fibrosis and calcifications, and the hyperintense component in type II lesions on T2WI was liquid silicone.

The remaining breast that underwent simple mastectomy had type I lesions diffusely scattered in the retroglandular portions of the breast. In addition, there was an ill-defined mass with a spiculated margin in the lateral part of the breast. The ill-defined mass was hypointense on T1WI, markedly hyperintense on FS T2WI, and exhibited fast, strong enhancement on FS post-contrast FS T1WI study (Fig. 4). Based on the MR imaging findings, the spiculated mass was diagnosed as a malignancy. Paraffinomas with infiltrating ductal carcinoma were found on histopathology; the type I lesions on MR imaging corresponded to paraffinomas and the ill-defined mass corresponded to the carcinoma.

The patients with the 51 breasts that did not undergo surgery were followed for at least 19 months (range, 19–54 mo; median, 27 mo; mean, 31.2 mo). Of these, four breasts underwent ultrasound-guided needle aspiration and cytology 21 days after MR imaging examination, and no evidence of malignancy was found in the specimens. The follow-up imaging of the 51 breasts that did not undergo surgery included MR imaging, sonography, and mammography, and neither definite interval changes nor the development of suspicious, growing lesions suggestive of malignancy were found.

Discussion

The role of ultrasonographic and mammographic evaluation in patients who have received direct paraffin or

### Table. Signal characteristics and enhancement pattern of breast paraffinomas and siliconomas on magnetic resonance (MR) imaging

<table>
<thead>
<tr>
<th>MR imaging pattern</th>
<th>T1WI SI</th>
<th>FS T2WI SI</th>
<th>Pre-contrast FS FSPGR SI</th>
<th>Post-contrast FS FSPGR E</th>
<th>Post-contrast FS T1WI E</th>
<th>Clinical outcome</th>
</tr>
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<tbody>
<tr>
<td>Type I</td>
<td>→ ↓ ↓</td>
<td>↓</td>
<td>↓ N</td>
<td>↓ N</td>
<td>8 breasts P*; 41 breasts S</td>
<td></td>
</tr>
<tr>
<td>Type II</td>
<td>→ ↑ and ↓</td>
<td>↓</td>
<td>↓ N</td>
<td>↓ N</td>
<td>9 breasts S</td>
<td></td>
</tr>
</tbody>
</table>

WI = weighted image; FS = fat-suppressed; FSPGR = fast spoiled gradient-recalled; SI = signal intensity; E = enhancement; → = intermediate SI; ↓ = hypointense; ↓ = markedly hypointense; N = no definite enhancement; P = paraffinomas; S = siliconomas; ↑ = hyperintense.

*One breast paraffinoma was associated with breast carcinoma.
silicone injections into the breast is limited, since the deeper structures of the breast parenchyma are obscured and superimposed malignancies cannot be excluded with confidence by either of these two imaging modalities. With various specially designed pulse sequences employed for their silicone-selectivity [6], such as FSE T2WI with water suppression, and three-point Dixon imaging [7, 15], MR imaging of the breast is usually used for the diagnosis of intra- or extracapsular breast implant ruptures and the evaluation of extracapsular free silicone that has spread from breast implants [4–7]. Studies have established that evaluation of breast cancers with contrast-enhanced dynamic MR imaging series has high sensitivity [8, 9]. In addition, contrast-enhanced MR imaging is superior to mammography in detecting recurrences in breast cancer patients who underwent mastectomy and breast reconstruction with an implant, especially when these cancers were located close to the chest wall [16]. Most malignant breast lesions, even early on, will show intense enhancement within 1 to 2 minutes of bolus injection of intravenous Gd-DTPA in post-contrast dynamic scans and a plateau phase of enhancement persists for 10 to 15 minutes; ill-defined spiculated margins are also seen [10–14]. Nevertheless, the absence of significant enhancement in post-contrast dynamic and delayed images excludes malignancy with high reliability [12]. In the present study, we evaluated the common features of direct paraffin or silicone injections in the breast on MR imaging. We also attempted to determine whether the MR imaging features of paraffinomas and siliconomas are different from those of breast cancer, given that the symptoms and signs of the patients enrolled in our study were not easily differentiable from those of patients with breast cancer. Accordingly, contrast-enhanced dynamic MR imaging series were performed for almost all patients in our study to determine whether there were any rapidly intense enhancing breast lesions. None of the breast lesions detected by MR imaging in our study exhibited definite enhancement in post-contrast dynamic and delayed series. These findings suggest that MR imaging findings allow malignancy to be excluded with a high degree of confidence. The non-enhancing lesions showed multiple well-defined round or ovoid nodules of various sizes in deep and superficial portions of the breast and large amorphous patches in the retroglandular portion of the breast. The contours of these lesions were not typical of that of breast cancers, which mostly present with ill-defined spiculated margins (Fig. 4).

In our study, the microscopic pictures of the paraffinomas and siliconomas were similar and presented as foreign body granulomas composed of foamy histiocytes, lymphoplasm cells, and multinucleated giant cells (Fig. 3). Minimal difference was found between the gross pictures of paraffinomas and siliconomas, since the paraffin oil and liquid silicone were seen in the vacuoles in both types of gross specimens. Paraffinomas and siliconomas exhibited two types of signal characteristics on various pulse sequences.
Fig. 2. Type II lesions on magnetic resonance (MR) images in a 47-year-old woman who underwent bilateral silicone breast injections more than 15 years ago and had suffered from bilateral breast masses for 10 years. A) Precontrast spin echo (SE) T1-weighted MR image in the sagittal plane of the right breast shows patches deep in the breast with intermediate signal intensity (arrows). B) Axial fast spin echo (FSE) T2-weighted MR image with fat suppression of the right breast reveals patches deep in the breast with hyperintense and hypointense components (arrows). The fibroglandular stromas (arrowheads) appear with a more superficial hyperintensity on T2-weighted MR image. C) The first post-contrast fat-suppressed dynamic three-dimensional (3-D) fast spoiled gradient-recalled (FSPGR) image shows no definite enhancement of the lesions (arrows) detected on T1-weighted and T2-weighted images. Multiple nodular lesions are also noted in the superficial portion of the breast (arrowheads), and are hypointense without definite enhancement. D) Mammography of the right breast in the craniocaudal view shows a huge patch of radio-opacity (arrows) in the breast, which obscures the parenchymal details of the deep portion of the breast, and multiple variously sized hyperdense nodules in the breast, some with rim calcifications (arrowheads).

sequences of MR images. All paraffinomas showed a type I pattern on MR imaging. It is presumed that the paraffin oil presents as markedly hypointense on FS images including FS T2WI and FS 3-D FSPGR, since it may contain a lipid component. Paraffin oil is a hydrocarbon that is not absorbed by the body. It has the general formula C_{n}H_{2n+2}, where n is an integer between 22 and 27 [3, 5]. On in vitro MR imaging analysis of the lipid and paraffin phantoms, both lipid and paraffin oil showed hyperintensity on non-FS T1WI [2]. However, the signal intensity of breast paraffinomas was lower than that of subcutaneous fat on non-FS T1WI [2]. It has been hypothesized that the prolonged accumulation of paraffin oil in breasts causes the paraffin to convert into a semisolid state, which generates little MR signal [2]. In addition, the microscopic pictures of granulomas, fibrosis, and calcifications in paraffinomas and most siliconomas in our study were also compatible with the type I pattern on MRI.

There were mixed hyperintense and hypointense components on T2WI in type II lesions on MRI. The hypointense component indicated the presence of granulomatous reactions with fibrosis, which was compatible with the microscopic features, and the hyperintense component on T2WI in type II lesions may indicate the spread of free liquid silicone, since silicone typically shows hyperintensity on T2WI [4, 6, 7, 15]. This is consistent with the results of our study,
A 60-year-old woman who received bilateral direct paraffin injections of the breasts more than 20 years prior to the examination presented with a 1-year history of hard, bilateral breast masses. Mammography and ultrasonography did not clearly depict the breast parenchymal details of bilateral breasts (not shown). Post-contrast spin echo T1-weighted magnetic resonance image with fat suppression obtained in the axial plane reveals hypointensity without evident enhancement of the lesions in deep portions of the breasts bilaterally (arrowheads), suggesting the presence of granulomas. An ill-defined spiculated mass with strong enhancement is noted (arrows) in the left breast. The spiculated mass shows hyperintensity on fat-suppressed T2-weighted image (not shown), suggesting malignancy. Paraffinomas and an infiltrating ductal carcinoma in the left breast were found on histopathology.

which showed that type II lesions only occurred in patients with a history of silicone injections. Silicone is a class of long-chain molecules of variable length, and medical-grade silicone most often consists of polydimethylsiloxane (PDMS) subunits (—Si [CH₃]₂—O—) of 400 to 600 subunits in length [15, 17]. The polar siloxane bond in silicone is subject to hydrolysis by the addition of water molecules under a variety of conditions, generating various proportions of water molecules surrounding the silicone [17]. The hydrogen protons in silicone PMDS subunits resonate at approximately 80 to 100 Hz lower than fat and 320 Hz lower than water under a 1.5-Tesla MR scanner, since the hydrogen protons in silicone molecules are more shielded than fat [17, 18], and the T1 relaxation time of silicone is longer than that of fat. The relaxation times (T1/T2 in milliseconds) of relevant materials are as follows: silicone, 1,000/100; fat, 250/40; and water, 1,000/350. Given these values, on T2WI, fat is hypointense, silicone is hyperintense, and water has the brightest signal of all [17]. Water molecules surrounding silicone molecules and the relatively homogeneous internal magnetic field of liquid silicone may contribute to the hyperintensity of silicone on T2WI. In this study, the gross picture of the operative breast siliconomas contained clear, pearly liquid silicone and this was compatible with the hyperintense component in type II lesions on MR imaging.

Most breast siliconomas showed a type I pattern with hypointensity on T2WI, and only small portions of breast siliconomas revealed a type I MR imaging pattern with a hyperintense component on T2WI (Table). The MR images in this series were different from the MR images of siliconomas due to breast implant rupture in the literature [4, 7]. This difference may have been due to two factors. First, the liquid silicone used for breast injection may have been non-medical-grade silicone, and the procedure may have been performed illicitly by non-physicians, with the injected silicone mixed with variously adulterated contaminants in various proportions [1, 4, 19–21]. The contaminating components in injected non-medical-grade silicone may have contributed to the different MR imaging findings compared with those from patients who received medical-grade silicone in breast implants. A purer composition of silicone with smaller proportions of adulterated contaminants can show hyperintensity on T2WI, as was seen for type II lesions on MR imaging. Second, the granulomatous reaction in siliconomas with a type I MR imaging pattern may be more severe than in those with a type II MR imaging pattern, thus causing a more hypointense signal on T2WI in type I lesions.

One patient in our series underwent left mastectomy, and paraffinomas and a breast cancer were found on histopathology. The paraffinomas showed type I lesions on MR imaging, while the malignant focus showed fast, intense enhancement and had a spiculated margin on MR imaging (Fig. 4), which is the typical MR imaging
manifestation of breast cancer and is different from the appearance of paraffinomas or siliconomas. The malignant lesion was not clearly visualized on ultrasonography and mammography.

In conclusion, the symptoms seen in patients with a history of direct paraffin or silicone breast injections make clinical exclusion of breast cancer difficult, and breast parenchymal details cannot be clearly visualized by ultrasonography or mammography. The MR imaging findings of breast paraffinomas or siliconomas are distinctly different from those of breast carcinomas. Breast MR imaging including post-contrast dynamic sequences offer superior resolution and improved delineation of the breast parenchyma, allowing the clinician to determine if there are malignant lesions superimposed on paraffinomas or siliconomas.

References