Water-Selective Spectral-Spatial Contrast-Enhanced Breast MRI for Cancer Detection in Patients with Extracapsular and Injected Free Silicone

J. Po[1], D. J. Margolis[2], C. H. Cunningham[3], R. J. Herfkens[2], D. M. Ikeda[2], B. L. Daniel[2]

[1]School of Medicine, Stanford University, Stanford, CA, United States, [2]Radiology, Stanford University, Stanford, CA, United States, [3]Electrical Engineering, Stanford University, Stanford, CA, United States

Introduction: Patients with free intra-parenchymal silicone from free injection or ruptured implant are difficult to evaluate for breast cancer. Current approaches to creating images of enhancing lesions in patients with free intra-parenchymal silicone include T1-weighted imaging with fat saturation [1] or subtraction imaging [1, 2] to remove signal from fat. Unfortunately the quality of fat-suppression that has been achieved in patients with free intraparenchymal silicone is limited [3]. 3DSSMT specifies a T1-weighted 3D gradient echo pulse sequence with a water-selective spectral-spatial (SS) excitation and an on-resonance magnetization transfer pulse that improves the differentiation between enhancing breast lesions and non-enhancing glandular tissue. The water-selective spectral-spatial pulse used in 3DSSMT employs a 16 ms narrow bandwidth excitation combined with oscillating gradients to excite a 200 hz FWHM range of frequencies corresponding to water within a well-defined sagittal slab volume of breast tissue [3, 4]. Non-water species, such as fat or silicone are not excited because their resonant frequencies remain outside the spectral band of the SS pulse (Figure 1A). In contrast, Silicone, with a resonant frequency about 100hz from the central Lipid peak, is near the edge of a typical fat-saturation pulse profile, and hence may or may not be completely suppressed by fat-saturation, depending on the local shim present. The purpose of this study was to investigate the ability of contrast-enhanced 3DSSMT MRI to produce robust water-specific images of contrast-enhancing breast lesions in patients with extravasated or free injected intraparenchymal silicone.

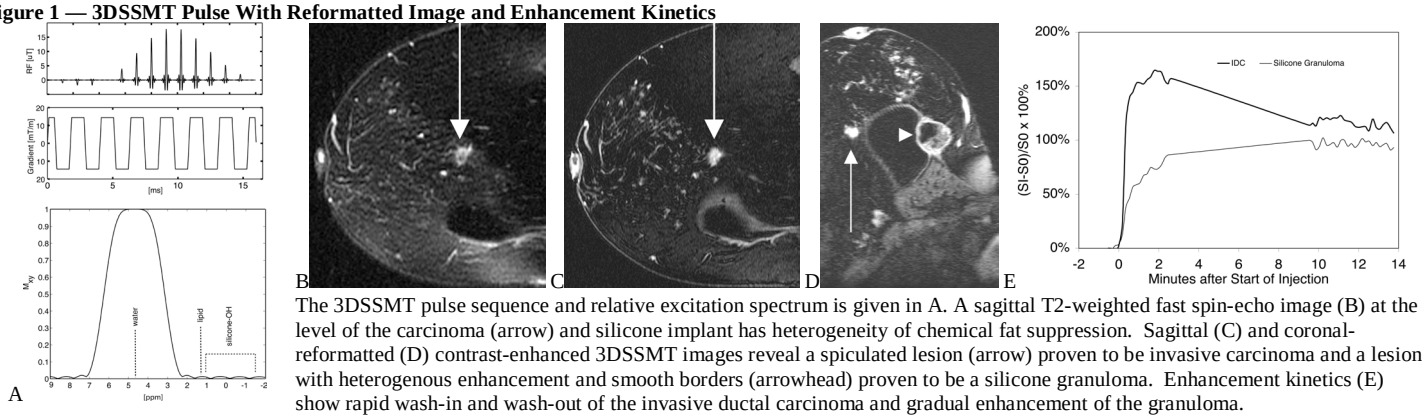
Methods: Using the proprietary Radbank search engine [5], we identified nine patients with history of direct silicone injections and four patients with MR evidence of extracapsular silicone implant rupture who had contrast-enhanced 3DSSMT breast MR scans between December 15, 1997, and June 28, 2004. The mean age of the twelve patients was 55.1 years, range 26-79. MRI was performed for clinical indications or as part of a protocol approved by our institution's Human Subjects Committee to evaluate the diagnostic accuracy of breast MRI. Examinations were performed in a 1.5 T scanner (Signa, GE Medical Systems, Milwaukee, WI) using a dedicated phased-array breast coil (MRI Devices, Waukesha, WI). Patients were imaged in the prone position. MR imaging included a T1-weighted spin echo axial sequence through the chest used to evaluate for symmetry and axillary lymphadenopathy (TR/TE 325/8 msec, 36 x 36 cm field of view, matrix 512 x 192, slice thickness of 5 mm), fat-saturated unilateral sagittal T2-weighted fast spin echo (FSE) (TR/TE 4000/102 msec, 20 x 20 cm field of view, matrix of 256 x 192, slice thickness of 4 mm, gap 4 mm, 32 slices), and pre- and post-gadolinium contrast 3DSSMT in all patients [TR/TE 28/8 msec, 20 x 20 cm field of view, matrix 256 x 128 (pre) or 512 x 192 (post), slice thickness 1.5-4 mm, gap 4 mm, 50˚ flip angle]. Gadolinium contrast material (Prohance, Bracco Diagnostics, Princeton, NJ, or Magnevist, Berlex, Berlin, or Omniscan, Nycomed, Auckland) dosed at 0.1 mmol/kg was injected intravenously at a rate of 2 ml/sec. Four patients had bilateral breast scans, with each breast scanned on a different day. Ten breasts were scanned with short-τ inversion recovery (TR/TE 4000-5000/65 msec, 20 x 20 cm field of view, matrix 256 x 192, slice thickness of 4 mm, gap 4 mm), with and without water saturation, to confirm the presence and view the distribution of extracapsular extravasated or free injected silicone. Silicone-specific three-point Dixon spin echo sequences [6, 7] were performed as well in six breast scans. Imaging and biopsy reports and the associated and follow-up MRI, X-ray and ultrasound images were reviewed.

Results: Free silicone had low signal on 3DSSMT images in all patients. Normal enhancing structures (e.g. small vessels, the nipple region, and lymph nodes) were visible in all cases following contrast administration. Silicone on conventional fat-suppressed T2-weighted images was of variably high signal intensity. Fat suppression failed in multiple areas on T2-weighted FSE in four cases, and in five others fat suppression was relatively uniform except at the periphery; in no cases was chemical fat suppression uniform (Figure 1B). Two patients with areas of suspicious contrast enhancement underwent MRI-guided needle localization for biopsy. One patient's biopsy revealed tissue comprising fibrocystic change (age 60). In the other patient, the lesion with a sharp contrast enhancement curve appeared irregular with a spiculated border on contrast-enhanced 3DSSMT, raising the suspicion for malignancy (Figure 1C-E). This patient underwent biopsy of the suspicious lesion and an area of gradual benign-appearing enhancement aided by MRI wire-localization, which showed a well-differentiated invasive ductal carcinoma, 8 mm in its greatest dimension, and a silicone granuloma, respectively.

Conclusion: In this study we demonstrate the capacity of 3DSSMT to produce water-selective images of enhancing breast lesions with uniformly suppressed signal from both fat *and* silicone in all cases, providing an alternative to subtraction processing or fat saturation. Water-selective 3DSSMT provides superior fat and silicone suppression in patients with free silicone as compared with conventional fat-saturation. It enables direct, high quality, high spatial-resolution T1-weighted breast MR imaging of contrast enhancement without need for subtraction processing, and aids diagnosis of cancer in the breast with free silicone. In our index case, contrast-enhanced 3DSSMT detected a small mammographically occult cancer with sufficient resolution to reveal its suspicious irregular, spiculated border.

1. Cheung YC, Su MY, Ng SH, Lee KF, Chen SC, Lo YF. Lumpy silicone-injected breasts: enhanced MRI and microscopic correlation. *Clin Imaging* **2002**;26:397-404
2. Herborn CU, Marincek B, Erfmann D, et al. Breast augmentation and reconstructive surgery: MR imaging of implant rupture and malignancy. *Eur Radiol* **2002**;12:2198-2206
3. Leong CS, Daniel BL, Herfkens RJ,et al. Characterization of breast lesion morphology with delayed 3DSSMT:an adjunct to dynamic breast MRI. *J Magn Reson Imaging* **2000**;11:87-96
4. Meyer CH, Pauly JM, Macovski A, Nishimura DG. Simultaneous spatial and spectral selective excitation. *Magn Reson Med* **1990**;15:287-304
5. Rubin D, Desser T. Radbank: Building an Integrated Data Warehouse for Radiology Teaching, Process Improvement, and Research. In: *Radiological Society of North America*. Chicago, IL, **2003**
6. Ikeda DM, Borofsky HB, Herfkens RJ, Sawyer-Glover AM, Birdwell RL, Glover GH. Silicone breast implant rupture: pitfalls of magnetic resonance imaging and relative efficacies of magnetic resonance, mammography, and ultrasound. *Plast Reconstr Surg* **1999**;104:2054-2062
7. Schneider E, Chan TW. Selective MR imaging of silicone with the three-point Dixon technique. *Radiology* **1993**;187:89-93

Figure 1 — 3DSSMT Pulse With Reformatted Image and Enhancement Kinetics



The 3DSSMT pulse sequence and relative excitation spectrum is given in A. A sagittal T2-weighted fast spin-echo image (B) at the level of the carcinoma (arrow) and silicone implant has heterogeneity of chemical fat suppression. Sagittal (C) and coronal-reformatted (D) contrast-enhanced 3DSSMT images reveal a spiculated lesion (arrow) proven to be invasive carcinoma and a lesion with heterogenous enhancement and smooth borders (arrowhead) proven to be a silicone granuloma. Enhancement kinetics (E) show rapid wash-in and wash-out of the invasive ductal carcinoma and gradual enhancement of the granuloma.