Artifact Size Caused by Breast Tissue Marking Clips at 1.5T and 3T MRI: A Phantom Study

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Introduction: Breast tissue marking clips are widely deployed to help identify where a previous biopsy is performed. These marking clips can be imaged using mammography, ultrasound, and MRI for future localization of lesion sites that have previously been biopsied . Particularly, breast MRI has increasingly been used to evaluate breast cancer which is mammographically and clinically occult. The magnetic field inhomogeneities induced by the breast tissue marking clips (particularly metal clips) can generate imaging distortion and signal void artifacts which are used to localize the biopsy location in breast MRI. The sensitivity of MRI for future assessment of breast lesions surrounding the previous biopsy region may be compromised if the signal void size caused by the implanted clip is too large. Although this effect has been studied at 1.5T in a recent report [1], it is yet unknown how the signal void artifact's size varies at a higher field magnet (e. g., 3T). It is our intention to quantify and compare the signal void artifact size at both 1.5T and 3T clinical scanners using three pulse sequences in this preliminary study.

Marking Clips Studied: Nine commonly used commercially available tissue marking clips were tested. The clips studied were: Clip 1: MICROMARK II (stainless steel, D4HP2J 2012-06) by ETHICON ENDO-SURGERY, INC. Clip 2: MAMMO MARK (collagen plug with a Titanium clip, D4G814) by ETHICON ENDO-SURGERY, INC. Clip 3: UltraClip Tissue marker (Stainless Steel, 6060-8003) by INRAD. Clip 4: UltraClip II Tissue marker(Titanium, 6070-1003) by INRAD. Clip 5: imarC Tissue marker (pyrolytic carbon coated ceramic markers,Size: 2×4 mm, 0603010A) by Carbon Medical Technologies, Inc. Clip 6: imarC Tissue marker (pyrolytic carbon coated ceramic markers, Size: 1×3 mm, 0605025A) by Carbon Medical Technologies, Inc. Clip 7: Gel Mark Ultra Breast Biopsy Markers (Stainless Steel, 07C199) by Seno Rx Inc. Clip 8: Gel Mark UltraCor Breast Biopsy Markers (Stainless Steel, M07031905) by Seno Rx Inc. Clip 9: SenoMark (Titanium, M06081001) by Seno Rx Inc. The greatest diameters of all clips were between 2 and 3 mm. Of the clips tested, clips 5 and 6 are nonmetal, all other clips are metal.

Imaging Methods: All clips were immersed in a gel phantom with enough distance between them (>30mm) to avoid field interference effects. The size of the signal void artifact caused by the clips in the phantom were then assessed on both 1.5T and 3T scanners. A non-fat-suppressed, RF-spoiled 3D T1-weighted gradient recalled echo (GRE) sequence commonly used in DCE breast imaging was used on both scanners with TR/TE/FA=32/4.6/25°, FOV=160mm, spatial resolution of $1\times1\times2mm^3$, and water fat shift of 1.534 pixels (i.e., readout bandwidth = 22.6 kHz for 1.5T, and 45.3 kHz for 3T, low readout bandwidth (LBW) sequence). The same sequence was repeated with higher readout bandwidth of 139 kHz (1.5T) and 198 kHz (3T) (high readout bandwidth (HBW) sequence). In addition, TE=1.16ms was also tested with partial Fourier readout and high readout bandwidth to study change of TE on the effect of signal void artifact size on both scanners.

Artifact Size Quantification: To quantify the signal void artifact size caused by each clip, the following steps were taken. First, a slice with the maximum long axis signal void artifact size was selected by visual inspection and computer aided length measurement. Second, the average background gel signal (S_b) surrounding the clip artifact was measured. Third, the image was intensity thresholded with a value of $S_b/2$ to generate a binary image. In the binary image, the signal void artifact region had pixel intensity 0 and the gel background had 1. Fouth and last, the maximum dimension of the signal void artifact was measured and was defined as the signal void artifact size caused by the corresponding marking clip.

Results: Two combined images are shown in **Fig. 1**, demonstrating the maximum clip artifact size and the shape of each clip at 1.5T (**Fig.1a**) and 3T (**Fig.1b**). The measured signal void artifact size from each marking clip studied is presented in **Table 1**. At TE=4.6ms, both scanners showed signal void artifacts ~2-8 times larger than the metal clips themselves. The average signal void size was 10%~20% larger at 3T compared to that of 1.5T for the metallic clips. Increasing readout bandwidth without changing TE had little impact on signal void artifact size on both scanners. However, decreasing TE from 4.6 ms to 1.16 ms reduced the average artifact size at both 1.5T (11%) and 3T (5%). In addition, non-metal (carbon) markers (Clips 5 and 6) did not show much size difference using sequences with different TE or readout bandwidth.

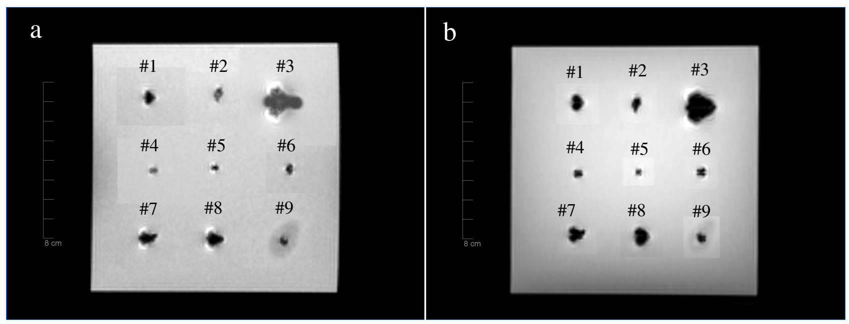

Fig. 1. Combined images to show the maximum artifact sizes of each breast tissue marking clip at 1.5T (a) and 3T (b). The corresponding MR sequence was a non-fat-suppressed 3D gradient echo sequence (TE=4.6ms, LBW).

Limitations of the Study: There are several limitations in this preliminary study: 1). Only in-plane signal void artifact size was measured and compared. The measured in-plane artifact size may vary significantly depending on the orientation of the implanted clips to the imaged slice. The slice direction artifact size was not measured since the spatial resolution is low compared to the clip sizes tested. 2). We also found that the high bandwidth scans on 1.5T had poor SNR, which may influence the accuracy of size measurement. 3). Only one typical spatial resolution ($1\times1\times2mm^3$) at both 1.5T and 3T was tested. Higher spatial resolution at 3T can be used due to higher inherent SNR, which reduces the metallic signal void artifact size; 4). The void artifact area on the image in addition to the maximum signal void dimension could also be measured for comparison. This information may be more relevant to determine how easy it is to localize the implanted breast clip.

Discussion: Although 3T magnets are known to offer higher SNR compared to 1.5T scanners, more magnetic field susceptibility artifacts are introduced for metallic marking clips. This could be a disadvantage of 3T scanners when used to detect and follow-up breast cancer adjacent to metallic tissue marking clips after biopsy. However, the signal void artifact size of metallic clips at 3T is only 10~20% larger than that of 1.5T at the tested spatial resolution ($1\times1\times2mm^3$). With higher spatial resolution achievable at 3T, the difference would have been smaller. It is further shown here that the shorter TE GRE sequence reduced the artifact size by only ~5-10% with great compromise on SNR. Overall, 3T MRI scanners can be used for the assessment of the breast lesions with clips following breast biopsy without generating too large signal void artifacts if tested spatial resolution or higher is used. Further study is warranted to investigate the impact of metallic clips on MR breast spectroscopy at both 1.5T and 3T.

Table 1. **Signal Void Artifact Size Caused by Different Marking Clips (size in mm)**

Pulse Sequence	Clip #1 (SS)		Clip #2 (Titanium)		Clip #3 (SS)		Clip #4 (Titanium)		Clip #5 (carbon)		Clip #6 (carbon)		Clip #7 (SS)		Clip #8 (SS)		Clip #9 (Titanium)	
	1.5T	3T	1.5T	3T	1.5T	3T	1.5T	3T	1.5T	3T	1.5T	3T	1.5T	3T	1.5T	3T	1.5T	3T
TE=4.6ms LBW	6.4	7.8	5.7	5.8	14.4	13.7	3.6	4.1	2.6	2.2	3.6	4.8	7.4	8.8	6.9	8.6	3.6	4.3
TE=4.6ms HBW	6.4	7.4	5.3	6.4	13.4	13.8	2.9	4.0	2.1	2.3	3.0	4.2	8.2	8.4	6.5	7.7	3.8	4.5
TE=1.16ms HBW	5.6	6.9	2.5	4.8	13.8	14.2	3.3	3.8	2.7	2.0	2.9	4.2	6.9	7.2	7.4	8.6	2.0	4.2

References:

(1) C.C. Genson, et al., "Effects on Breast MRI of Artifacts Caused by Metallic Tissue Marker Clips", AJR, 188, 372-6 (2007).