Development of a MR/ US/ X-Ray Compatible Marker for Breast Tumor Localization

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Introduction: MR-guided breast biopsy is necessary when a nonpalpable lesion is detected by MRI but occult to mammography and US. Needle localization is a standard procedure for surgical demarcation of breast lesions during surgery. Ideally the wire should be visable by intraoperative US imaging; however, needle visability can be suboptimal in 4-9% of surgical cases [1]. In order to ensure optimal visualization of a breast localiser, the marker should be visable on all three breast imaging modalities including mammography, US and MRI. This study presents a novel marker system which is optimized to give high contrast visualization on each imaging method and opens a new framework for image guided breast surgery.

Materials and Methods:

Materials: Biocompatible GL-0175 glass microspheres (MO-SCI Co., UK, diameter 0.4-0.6mm) and Aluminum 2017 microspheres(Salem Specialty Co., diameter 0.5mm, 0.7% and 10% iron) were suspended in a gelatin solution and then cast in 12 or 14 gauge biopsy needle to form a cylindrical marker 8mm long with 2.1 or 1.8mm diameter respectively (Fig.1). In order to control the T2* of the marker, varying number of iron containing aluminum microspheres were added. The US contrast was modulated by adjusting the number of glass and aluminum microspheres added to the gelatin matrix. The optimal mixture was determined to provide maximum US contrast while providing clear localization of the marker in MRI. The studies were performed on gelatin phantoms and tissue experiments using chicken breast. The gelatin phantoms were loaded with 4% silicon by weight to provide diffuse US scattering.

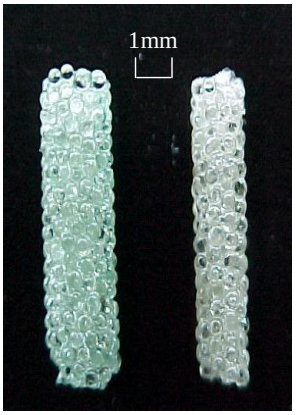

Fig.1: Photograph of marker

MRI Experiments: All MR studies were performed on 1.5 T MRI system, Signa, GE Medical System using a 5-inch surface coil. A 2D GRE (TR 25ms, TE 10ms, FA 30°, matrix 256, FOV 15cm) was used for demonstrating MRI contrast of the marker. T2* measurements were performed with a 2D GRE (TR 2500ms, with TE varying from 4 to 40ms, FA 30°, BW 15.6KHz, matrix 256, FOV 15cm) on markers with different iron content.

US Experiments : US images are acquired with Philips ATL HDI-5000 using a linear phased array 5-12MHz (L12-5, ATL) transducer.

X-Ray Experiments: This was performed with a GE Senographe 2000D for X-Ray imaging using a tube voltage of KVP 25 and tube current of 87 mA.

Results: A series of phantom and in vitro tissue experiments were used to create the proper marker composition. Quantitative 1/T2* analysis (Fig.2 (b)) showed increasing 1/T2* with iron content. Our objective is to find the optimal iron content that allows clear definition of the marker location without excessive distortion of the MR imaging from the B_0 inhomogeneities of the iron containing marker. We have found this condition was met with a marker containing ~ 80 glass spheres and a single aluminum sphere (52ug iron) to give a T2* of 6.6 ms. This is shown in Fig.2 (a) where we show an axial MRI of chicken breast phantom which shows clear visualization of the marker location.

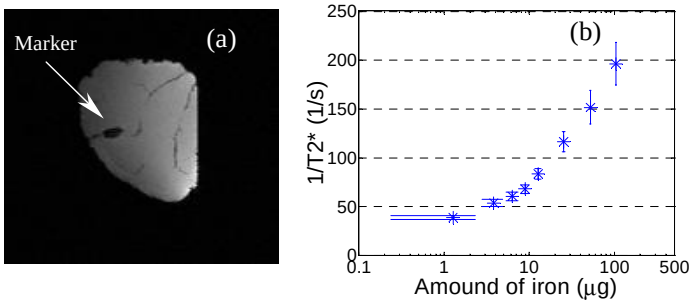

Fig. 2: (a) Axial MRI of chicken breast with marker containing 52ug iron, (b) 1/T2* as a function of iron content

The US image of the same marker is shown in Fig3. (a) where the marker appears as a hyperintense structure arising from the high reflectivity of the GL-0175 glass microspheres. Echo intensity was plotted in Fig.3 (b) as a function of glass concentration and shows that the optimal concentration should be greater than 40% weight by volume.

The X-Ray image of the chicken breast phantom (Fig 4), also clearly demonstrates the marker on the left upper of the image.

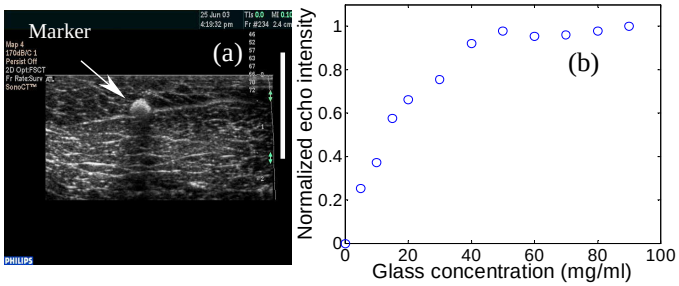

Fig. 3: (a) Ultrasound image,
(b) Normalized echo intensity for different glass concentration

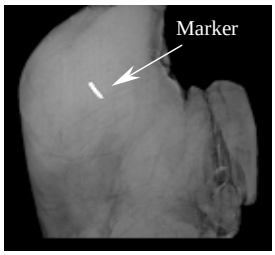

Fig.4: X-Ray image

Discussion and Conclusions: Through the combined use of glass and iron containing aluminum microspheres in a gelatin matrix, it is possible to construct a marker which is clearly visualized with MR, US and X-Ray imaging. The marker is small and can be easily introduced into tissue through either a 12 or 14 gauge biopsy needle. While designed for breast applications, the same marker construct could be used for other applications including liver and kidney interventions. Further study is needed to test the long-term stability of the marker and to assess the degree to which the marker may migrate throughout the tissue with time after insertion.

References: **1.** Harms SE., et al., ISMRM, 2002. **2.** Harlow SP., et al., J Am Coll Surgeons 189, 241, 1999.