Immobilization of Breast Tissue Using Small Beads for MR-Guided Breast Interventions

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INTRODUCTION

It is necessary to immobilize the tissue for MR-guided breast interventions in addition to preventing breast tissue motion due to breathing or cardiac pulsatility. Biopsy or therapy needles distort the breast upon insertion and cause the internal structures to move shifting the target from its original position. Conventional methods of stabilizing the breast during an MR-guided intervention use a planar approach in which the breast is compressed between two parallel stabilization plates [1]. However, the plates distort the tissue into an unnatural form that may also impair post contrast lesion enhancement if compression is too high. A 3D radial approach was developed to MR-guided breast interventions and an inflatable bladder was implemented to provide 3D tissue immobilization within a transmit/receive solenoid RF-coil [2,3]. However, in the bladder design, the pressure was not uniform about the tissue surface due to an insertion window necessary to maintain the pressure during the intervention. We present a novel method that will uniformly stabilize the breast using small beads, preserving the natural breast shape, and allow a needle insertion from any angle without compromising the immobilization.

METHODS

The MR-guided system that generated this approach includes integrated dual solenoid coils, in which the conductor of each coil makes three turns around a breast support cup (Fig 1). The patient lies prone with their breasts in the breast support cups. In an effort to preserve the natural shape of a distended breast with a prone patient, and conform to the 3D concept of an MR-guided device, small lightweight polypropylene beads (3/8 in. diameter) were investigated for filling the space in between the tissue and breast support cup. The beads distribute equal pressure over the entire surface area of the breast, thus preserving its shape and minimizing the total amount of pressure needed to immobilize the tissue.

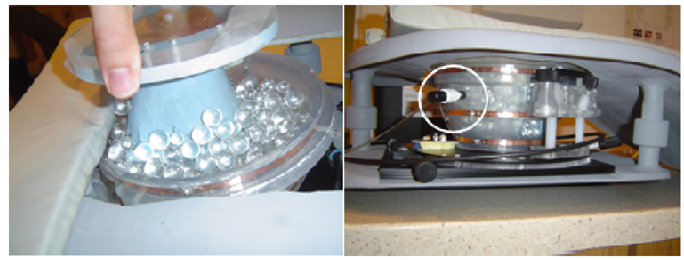

Figure 1. (left) Chicken breast within a surgical glove was placed within the coil and surrounded by small beads to provide uniform pressure around the entire surface area of the breast. (right) Lateral view of a biopsy needle insertion through the beads into the tissue (white circle). The three conductor turns of the solenoid coil are also visible.

Two experiments were performed. The first experiment tested the tissue immobilization capability of the small bead concept. Two chicken breasts placed within a surgical hand glove served as the tissue phantom. A 1.5T system (GE Signa HDx Twin-speed, Waukesha, WI) was used to visualize distortion without the beads added in response to the insertion of a biopsy needle. This was repeated with the small beads installed around the breast. The trajectory of the needle insertion appeared unaffected by the small beads. In the second experiment, we evaluated the capability of the small bead method to preserve the natural shape of the breast in a human volunteer. A high resolution 3D T1-weighted acquisition (sagittal, fat saturated, TR/TE/FA 21.5/4.2/30°, matrix 256x256, FOV 16cm, slice thickness 3.0mm) was performed on the left breast of a volunteer with no method of stabilization. A small force from a blunt rod was used to simulate the force from a needle insertion on the lateral surface of the breast. Small beads were then installed manually around the breast within the support cup so that a small amount of pressure was added uniformly to the breast surface. The same acquisition was used to acquire another image volume with the small beads around the breast. Images were compared before and after application of a blunt rod for the two cases.

RESULTS

In the phantom, the introduction of small beads into the free space between the breast tissue and the breast support cup prevented peripheral and internal tissue movement during a biopsy needle insertion (Fig 2). A human volunteer study showed diagnostic image quality and no distortion of internal structures (Fig 3). Small dimples were evident along the periphery due to the shape and finite size of the small beads. However, these small distortions are not likely to interfere with internal structures. Although motion did occur due to the small force from the blunt rod with the application of the small beads, it was less than the apparent motion without immobilization (Fig. 3, bottom).

DISCUSSION

The natural shape preservation and tissue immobilization attained by the small beads may allow more reproducible breast exams free of motion artifact. In 2007, the American Cancer Society (ACS) recommended that women of high risk for breast cancer be screened with MRI on a yearly basis. Thus, the number of breast image comparisons will greatly increase in the near future, mandating the need for reproducible breast MRI exams. Future work will evaluate the reproducibility of breast positioning in the solenoid coil with the small bead technique.

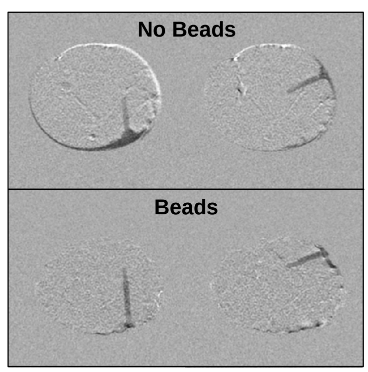

Figure 2. Insertion of biopsy needle into animal tissue model. Difference images show motion relative to a baseline image. (top) Without beads, slight tissue motion was observed as evident by the bright and dark signal around the periphery of the tissue. (bottom) With the beads, immobilization of the tissue was considerably improved.

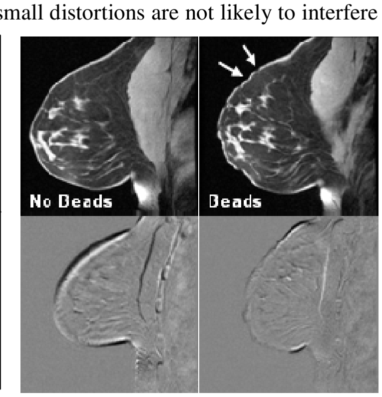

Figure 3. Sagittal view with fat suppression of a volunteer without beads (left column) and with beads (right column). Although superficial dimples appear, the internal structures of the breast are undistorted compared to the natural pendant breast. A small force was introduced on the lateral side of the breast. Displacement is displayed using subtraction images (bottom).

REFERENCES

[1] Veltman et al. Invest Radiol. **40:**379-84 (2005). **[2]** Smith et al. *Proc. of the 17th Annual Meeting of ISMRM.* #1212 (2008). **[3]** Smith et al. *Medical Physics.* **35**(8): p. 3779-3786 (2008).