Novel circumferential immobilization of breast tissue displacement during MR-guided procedures: initial results

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INTRODUCTION The performance of image-guided devices for breast procedures is dependent on how well the tissue is stabilized during interventions. Novel MR-compatible devices for breast interventions have been previously developed by various groups using conventional 2D compression plates for breast tissue immobilization during a procedure[1,2]. However, these devices typically distort the anatomy and cause discomfort for many women. Also, it is known that strong breast compression may impair lesion enhancement, making it more difficult to plan interventional procedures[3]. Breast tissue immobilization that distributes force more circumferentially over the surface area of the breast is desired. The purpose of this study is to evaluate the performance of a 3D tissue immobilization concept using circumferential air bladders to stabilize breast tissue during MR-guided breast procedures.

METHODS Tissue immobilization tests were performed using a previously described 3D MR-guided device and dedicated coil[4]. The 3D immobilization prototype consisted of three air bladders connected in parallel to a common pressure source (at this early stage, a small hand pump). The three air bladders reside within the breast coil and surround the tissue circumferentially (Fig. 1). The gel breast phantom typically used to test the accuracy of the device in localizing lesions was too rigid to represent the mobility of a distended breast. Therefore, three chicken breasts were laid in a thin plastic layer to mimic breast tissue mobility. Small tubes containing Gadolinium contrast agent were used as reference markers implanted into the chicken breasts to assess the extent of tissue displacement upon insertion of a polypropylene rod (diameter 0.125 in) with a trocar tip. The trocar was used to mimic MR-guided biopsy procedures performed with a commercially available MR-compatible vacuum assisted biopsy system (Suros, Indianapolis, IN). Using a 1.5T MRI system (GE EXCITE II Twin-speed, Waukesha, WI), a 3D SPGR MRI sequence (TR/TE/FA 7 ms/4.5 ms/30°) was used to create a 3D image volume that was loaded into a custom graphical user interface. The coordinates of one of the implanted markers was loaded into the planning algorithm resulting in an output of 3D cylindrical coordinates for the device positioning. Accessing the target was attempted with the trocar and subsequent tissue displacement was observed by incrementally inserting 10 mm until the target was reached. After each increment, a 2D coronal image of the trocar was acquired with a conventional 2D GRE sequence. Difference images (Fig. 2) were created by subtracting subsequent insertion images from the initial baseline image taken without any insertion. Any bright or dark signal represents tissue that displaced relative to the baseline image during the trocar insertion. The first study did not have the bladders inflated, and thus no immobilization was performed (Fig. 2a). The second study was performed with the bladders inflated (Fig. 2b). The resulting 2D images from the two studies were compared to assess the capabilities of the 3D immobilization concept. The accuracy of the device and planning algorithm was previously reported and was not the focus of this study[4].

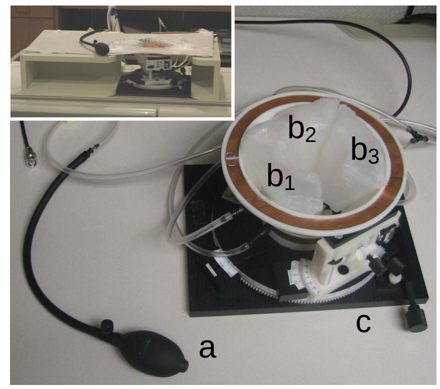

Figure 1. MR-guided device, breast coil, and 3D bladder prototype. A hand pump (a) is used to inflate the three bladders (b_{1-3}). The trocar is inserted through the probe guide assembly (c) within the available window between bladders b_1 and b_3. Experimental setup shown (upper left) with chicken breast in coil surrounded by bladders on the scanner table.

RESULTS When the air bladder was not inflated, a considerable amount of tissue was displaced due to the insertion of the trocar (Fig. 2a). The bright and dark points (white arrows) represent where the markers were located before and after insertion respectively. Figure 2b displays the result when the air bladders were inflated around the breast phantom. The lack of bright or dark signal demonstrates improved tissue immobilization during trocar insertion. The only considerable difference from the baseline is the trocar itself (dark line). The two sets of difference images are shown with the same color-scale.

DISCUSSION The preliminary results reported here demonstrate that a 3D bladder system pressurized with air can stabilize chicken breast tissue when a trocar is inserted during MR-guided interventional procedures. The pressure used for this study was approximately 0.5 psi, compared to mammographic plates that operate around the same pressure. However, the pressure of mammographic plates deform the tissue considerably. It is apparent from Figure 2b that although the tissue is stabilized when the air bladders are inflated, the tissue is also deformed by the bladders, although comparably less than mammography or other MR-guided planar breast compressions. It can also be seen in Figure 2b that the tissue is pushed through the insertion window (star) where there is no bladder pressure. This is a limitation of the number and shape of the air bladders, which has not been optimized. It is our goal to optimize the bladder shape to minimize anatomic distortion upon inflation with the force more evenly distributed around the breast. We will also investigate the amount of pressure required to achieve the desired stabilization, and demonstrate through patient studies that the compression is better tolerated than planar compression.

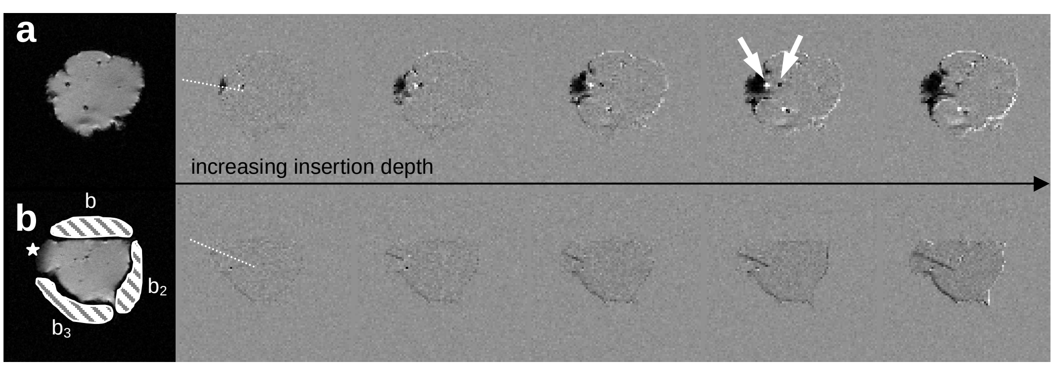

Figure 2. Coronal difference images (right) obtained by subtracting the baseline image (left) from subsequent images acquired after incrementally increasing the insertion depth along the planned trajectory (dotted line). Bright or dark signal in difference images demonstrates tissue displacement during insertion relative to the appropriate baseline image. Bright and dark points (white arrows) represent where the nearest markers were located before and after insertion, respectively. Relative tissue movement during trocar insertion is shown in the tissue phantom (a) without 3D bladders and (b) with 3D bladders (b_{1-3} as shown in Fig. 1). The area without bladder stabilization (star) is the region where trocar insertion occurs.

REFERENCES

1. Fischer et al. *IEEE* 2004; 2530-2534. **2.** Larson et al. *ASME* 2004; **126**:458-465. **3.** Kuhl et al. *Radiology* 1997; **205P**:538. **4.** Smith et al. *Proc. of the 16th Annual Meeting of ISMRM.* 1107 (2007).

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