# Avoiding a Systematic Error in Assessing Fat Graft Survival in the Breast with Repeated Magnetic Resonance Imaging

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**Summary:** Several techniques for measuring breast volume (BV) are based on examining the breast on magnetic resonance imaging. However, when techniques designed to measure total BV are used to quantify BV changes, for example, after fat grafting, a systematic error is introduced because BV changes lead to contour alterations of the breast. The volume of the altered breast includes not only the injected volume but also tissue previously surrounding the breast. Therefore, the quantitative difference in BV before and after augmentation will differ from the injected volume. Here, we present a new technique to measure BV changes that compensates for this systematic error by defining the boundaries of the breast to immovable osseous pointers. This approach avoids the misinterpretation of tissue included within the expanded boundaries as graft tissue. This new method of analysis may be a reliable tool for assessing BV changes to determine fat graft retention and may be useful for evaluating and comparing available surgical techniques for breast augmentation and reconstruction using fat grafting. *(Plast Reconstr Surg Glob Open 2016;4:e1023; doi: 10.1097/GOX.0000000000001023; Published online 8 September 2016.)*

**Avoiding a Systematic Error in Assessing Fat Grafts**

Several modalities for assessing breast volume (BV) have been published, including water displacement, imprint casts, 3D photography,[1] computed tomography, and magnetic resonance imaging (MRI).[2,3] Three-dimensional photography has gained popularity because of its speed and accessibility[4,5]; however, this technique is clearly inferior to MRI because of its lower accuracy.[2,4,6–9] To compare the many techniques used to improve graft survival, a reliable method to quantify BV is essential. Previous techniques for quantifying BV using MRI generally follow the same principle[2]: An observer identifies the boundaries of the breast, and the volume within these boundaries is calculated. Because there is no clear anatomical segregation between the breast and the surrounding tissue, the boundaries are always defined by contours. As the mammary gland is a type of apocrine gland lying in the subcutaneous fatty tissue, there is no anatomical border between the breast and the surrounding tissue. MRI techniques have also been used to measure BV changes after fat grafting (FG) procedures,[4,10–14] where the difference in volume is determined by subtraction. Unfortunately, the techniques mentioned above introduce a systematic error because the contour of the breast changes after an alteration in breast size. When the volume of the breast increases, its boundaries expand, and the boundaries diminish when the volume decreases. Boundary changes will either include or exclude some extra tissue contained within the altered breast boundaries. The addition or subtraction of this extra tissue is a source of error when using MRI techniques to estimate BV changes after an FG procedure (Fig. 1). Areas *A* and *C* in Figure 1 correspond to the size of the error in the estimation of fat graft retention when using techniques that solely rely on outlining the contour of the breast. Therefore, MRI techniques used to determine graft survival should not be based on the dif-

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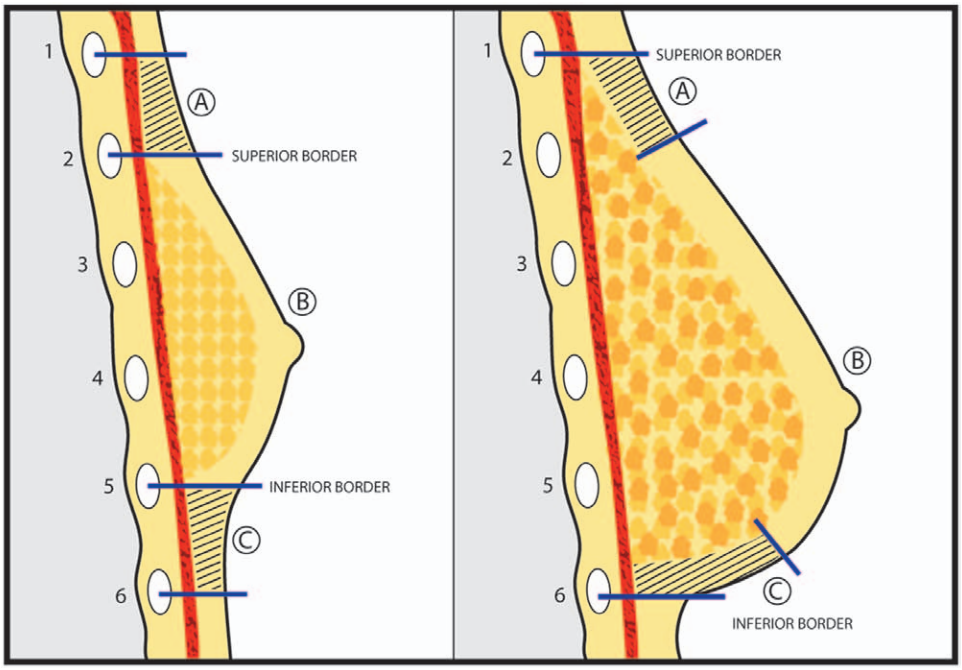


**Fig. 1.** Contours of the breast before and after enlargement by FG. Along with the injected graft, additional tissue is included within the borders of the breast as the enlargement creates a new breast contour. Areas *A* and *C* illustrate this additional tissue, which becomes part of the tissue that is added to the breast during the FG procedure. To avoid a systematic error and accurately estimate graft retention, this additional tissue should be included in all MRI volume measurements.

ference between 2 volume measurements that are based exclusively on the breast contour.

### Assessment of Volume Changes Based on Fixed Osseous Markers

To accurately assess changes in BV after FG procedures, we propose a new principle for quantifying BV changes based on multiple MRI scans of the breast as it undergoes volume change. Initially, it is important to consider the largest total volume expected when quantifying the BV.[15,16] The boundaries used in the initial volume assessment will serve as the reference for all future volumetric measurements. The boundaries of the breast are defined, and their relation to immovable osseous pointers is established, which enables the boundaries selected on the reference scan to be precisely superimposed on all other scans of the same patient, making the volumes comparable.

### Clinical Importance of Comparable End Points of Breast Volumetry in FG

FG has become an important procedure in breast reconstruction and augmentation.[17,18] Fat grafts undergo some resorption over time, and research on improving graft survival includes selection of the best donor site, optimization of fat harvest, injection techniques, and preparation of the recipient bed.[19] More recently, improvements in fat graft survival have been achieved by adding stromal vascular fraction[20] or ex vivo expanded autologous stem cells[21] to the graft.

## PATIENTS AND METHODS

To test this new method for the volumetric analysis of BV changes using MRI, 4 women were offered bilateral breast augmentation by FG and an average graft volume of 288 $cm^3$ per breast. The use of noncontrast MRI of the breast was approved by the Danish Ethics Committee. MRI was performed 4 times: (1) before surgery (preoperative), (2) immediately after surgery (<3 h), (3) 4 months postoperative, and (4) 1 year postoperative. The scan performed immediately after surgery was selected as the reference because the breast has the most extended borders at that time.

A 3.0-Tesla 4-channel breast coil was used (Siemens Magnetom Verio; Erlangen, Germany). Volumetric analysis was performed on an axial breath-hold DIXON sequence with 72 slices and 3-mm slice thickness. A coronal scan was obtained to determine the position of the manubriosternal joint along the *z* axis. Acquisition time was less than 5 minutes.

The borders were marked on all 4 scans by 4 steps: (1) The superior and inferior borders were planes that were parallel to the transverse plane. The selected borders were translated to a fixed distance from the manubriosternal joint along the *z* axis (Fig. 2B). (2) The medial border corresponded to the midsagittal plane. (3) The lateral border corresponded to a coronal plane translated to a fixed distance posterior to the sternum position (Fig. 2C), which was typically 1–3 cm depending on the breast size and the contour of the anterior thoracic wall. (4) Finally, the anterior border corresponded to the transition from the skin to the surrounding air. The posterior border corresponded

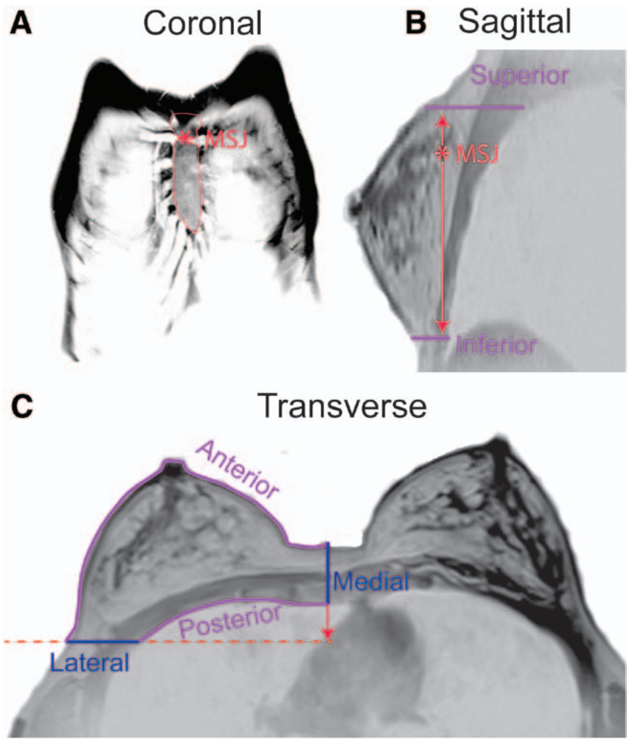


**Fig. 2.** A–C, Delineation in the 3 axes of the breast. To analyze graft survival, the borders of the breast must be reproducible in all images acquired at any given time. *Manubriosternal joint.

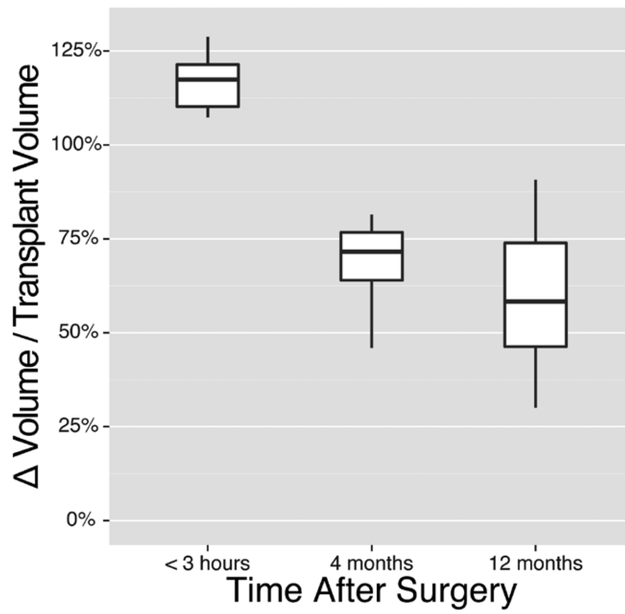


**Fig. 3.** The average percentage of fat graft volume retention is shown in 4 patients after bilateral breast augmentation. The range and half range are plotted at the 3 postoperative time points.

to the transition from the costae to the pleura. This transition was traced manually on all transverse cross sections within the superior and inferior boundaries. After selecting the borders, the comparable volumes were calculated by multiplying the included area for each slice by the slice thickness. The preoperative scan was used to determine the baseline BV. The percentage of volume change of injected fat was calculated by the following equation to determine fat graft retention: ([postop BV−preop BV]/transplant volume) × 100% = percentage volume change of transplant.

## RESULTS

The BV changes and total BV values are shown in Table 1, and the fat graft retention data are shown in Figure 3. The immediate postoperative BV change exceeded 100% of the injected fat for all patients and was caused by temporary tissue edema (Fig. 3). The fat grafts were fully integrated into the native adipose tissue in the breast at 4 months and at 1 year after surgery as assessed by MRI. This method was easy to apply to all the included patients' scans. Each MRI examination was 15 minutes in duration, and processing and analysis of the images to determine the change in BV were completed in approximately 2 hours.

## SUMMARY

We have proposed a new method for estimating BV changes after FG procedures using MRI and volumetric analysis. This method has the potential to overcome a systematic error that occurs when breast contour–based analysis is performed, and this method may replace previous BV-measuring techniques. The method uses a strategy that focuses on providing accurate and reproducible data on BV change, which is crucial in the assessment of fat graft survival. The widespread use of this new technique depends on the availability of MRI facilities. Therefore, in its current form, this technique is primarily suited to clinical researchers who require very accurate data on fat graft retention. A drawback of this technique in its current form is that the postprocessing of each scan is time consuming (2 ± 1 h per scan). Software is currently being

**Table 1. Breast Volume Change, cm³ (Total Breast Volume, cm³)**

| | | Preoperative | >3 h | 4 mo | 12 mo | Fat Graft (mL) |
|---|---|---|---|---|---|---|
| Patient 1 | Right breast | 0 (593.0) | 332.2 (925.1) | 212.2 (805.1) | 152.0 (745.0) | 300 |
| | Left breast | 0 (592.7) | 326.1 (918.8) | 206.5 (799.1) | 143.4 (736.5) | 300 |
| Patient 2 | Right breast | 0 (575.9) | 308.2 (884.1) | 119.5 (695.4) | 171.5 (747.4) | 260 |
| | Left breast | 0 (543.3) | 334.8 (878.1) | 128.4 (671.7) | 180.0 (723.3) | 260 |
| Patient 3 | Right breast | 0 (747.8) | 391.6 (1139.4) | 266.4 (1014.2) | 296.7 (1044.5) | 327 |
| | Left breast | 0 (726.2) | 383.6 (1109.8) | 265.7 (991.9) | 290.0 (1016.2) | 330 |
| Patient 4 | Right breast | 0 (967.8) | 300.5 (1268.3) | 202.9 (1170.7) | 84.1 (1051.9) | 280 |
| | Left breast | 0 (933.5) | 315.7 (1249.2) | 188.7 (1122.2) | 103.4 (1036.9) | 250 |

developed by our group to address this issue and holds the potential to lower the processing time of each scan to less than 5 minutes.

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### PATIENT CONSENT

*All patients provided written informed consent to participate in MRI of the breast.*

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