Research article

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The Role of Non-enhanced MRI in Measuring Flap Volume Variability in Post-bariatric Women after Mastopexy with Autologous Tissue Augmentation Using an AICAP Flap

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Abstract

Aim: To evaluate the capability of non-enhanced breast MRI to assess flap volume variability in post-bariatric patients who underwent mastopexy in a reproducible way.

Materials and Methods: Ten bariatric patients, treated with mastopexy using anterior intercostal artery perforator (AICAP) flap for autologous tissue breast augmentation, were enrolled in this study. All patients performed a breast Magnetic Resonance (MR) exam after surgery, in a period ranged from 177 and 838 days. The real flap volume, measured before mastopexy, and the flap volume calculated from MRI segmentation, was compared. Two radiologists performed the segmentation of the flap and of the whole breast, manually drawing an area of interest on MR images. The process was repeated for each patient, each breast and each slice 5 times, on axial T2W-TIRM, axial T1W-3D FS and sagittal T1W-3D images. Then, the flap and the breast 3D volumes were automatically generated combining multiple segmentations. The reproducibility of the measurements was evaluated, analyzing inter-and intra-observer agreement, and the most accurate MRI sequence was identified.

Results: A significant difference between the mean flap volume before mastopexy and the mean MRI flap volume was detected, with an absolute mean decrease of 46,85% (105,89 cm^3) (p<0.05). There was no significant difference among the measurements performed by the same reader and by the two readers. The lowest variability was identified on T1W-FS, evaluated as the best performing sequences.

Conclusion: MRI breast segmentation is an accurate and reproducible method for breast flap volume assessment and can provide important quantitative information to surgeons.

Introduction

Patients who underwent bariatric surgery procedures have a massive loss of weight. The loss of weight determines an improvement in health status but also some negative physical sequelae due to redundant skin and subcutaneous tissue. Among these sequelae, breast fat atrophy is an important source of distress for women patients, who may benefit from plastic treatments [1-4].

Breast mastopexy is a possible solution. It is performed with optimal results, even if standard mastopexy is frequently inadequate and a secondary breast augmentation is required [5,6]. Among some usual different techniques, autologous tissue augmentation, using fasciocutaneous flap from redundant areas, is particularly indicated in post-bariatric patients [7]. Several authors, in the last decades, demonstrated that the flap based on the intercostal artery perforator (ICAP) provides adequate breast volume and contour without breast implant placement [1-8]. In particular, the anterior ICAP (AICAP), based on perforators originating from the intercostal vessels through the rectus abdominals or the external oblique muscles, has a short

pedicle that makes it suitable to close defects that extend over the inferior or medial quadrants of the breast.

Breast symmetry is the primary surgery aim in these patients and a correct volume assessment of the breasts is a fundamental prerequisite to obtain optimal surgical results [9-11]. There are different pre-and post-operatively measurement methods used by surgeons for breast volume assessment. The methods fall into five categories: 1) anthropomorphic method, measuring edge to edge the region of interest, 2) mammography, 3) Archimedean method, based on water displacement and thermoplastic fusion, using a 3D negative cast of the breast, 4) 3D laser scanner and 5) magnetic resonance imaging (MRI) [11,12]. There are still some gaps between image-based volumetric estimation and actual breast weight [12,13].

We evaluated the flap volume variability, before and after mastopexy performed using AICAP flap, comparing the real anatomic volume of fasciocutaneous flap and the flap volume calculated on non-enhanced breast MR images after surgery. For each breast, MRI flap volume was automatically calculated from the flap manual segmentations previously performed by two different operators, on both T1-weighted and T2-weighted sequences.

Subsequently, we evaluated the non-enhanced MRI performance in breast volume assessment and the reproducibility of the segmentation

method, analyzing inter- and intra-observer agreement. Finally, we identified the best sequence to assess the breast volume.

Materials and Methods

In this retrospective study, all bariatric patients treated with mastopexy at the Department of Plastic Surgery of our center, "Campus Bio-Medico" University of Rome, between April 2013 and November 2014 were included. Mastopexy was performed by two senior general surgeons with 10 and 12 years of experience, using AICAP flap for autologous tissue breast augmentation in all cases. For the surgical intervention, an intercostal perforator has been identified and dissected to its origin from the intercostal bundle through the split serratus anterior muscle. The pedicle was dissected within the periosteum under the rib lengthens and the AICAP flap was transferred to the breast defect. Before the transfer, flap dimension and flap volume were calculated using the antropomorphic method and the data were stored in a clinical personal archive (Table 1).

Patient	Surgery date	Flap dimension (cm)	Initial volume (cm^3)	MRI exam date	Days after surgery	Mean MRI volume (cm^3)	Volume decrease
1	13/04/2013	15 × 8 × .5	180	30/07/2015	838	62.49	65.28
2	26/04/2013	14 × 1.6	168	29/01/2015	643	109.36	34.9
3	17/05/2013	15 × 12 × 2	360	29/01/2015	622	256.25	28.88
4	07/07/2013	10 × 12 × 2.5	300	22/01/2015	564	194.86	35.05
5	13/09/2013	10 × 10 × 1.5	150	29/01/2015	503	95.21	36.52
6	01/03/2014	15 × 10 × 2	300	18/03/2015	382	150.47	49.84
7	20/05/2014	15 × 8 × 1.5	180	26/11/2014	190	53.03	70.53
8	10/07/2014	15 × 10 × 1.5	225	21/01/2015	195	97.36	56.72
9	19/07/2014	15 × 10 × 1.6	225	20/01/2015	185	178.36	20.73
10	04/10/2014	15 × 8 × 2	240	30/03/2015	177	71.69	70.12

Table 1: Patient's surgery and MRI exams parameters.

Patient's demographic data and BMI were also collected before breast MRI execution. All patients underwent non-enhanced breast MRI after a variable follow-up period, voluntarily. An informed consensus was signed by each patient. All breasts MRI were performed from November 2014 to July 2015, so that the time interval between the AICAP flap mastopexy and the breast MRI examination ranged from 177 and 838 days.

The adopted exclusion criteria were: MRI absolute and relative contraindications, presence of implants or metallic clips, psychiatric disorders and uncooperative behaviour [14].

All MRI examinations were performed on a 1.5 T magnet (Symphony Siemens, Munich, FRG) using a dedicated multi-channel breast coil (CP BREAST ARRAY) with the patient in prone position, head first, and with arms up the head. Both the breasts were placed into the coils and a slight compression was carried out in latero-lateral direction in order to minimize movement artifacts. After the localizer sequences, taken in three orthogonal planes, the following sequences were acquired:

- Axial T2-weighted Turbo Inversion Recovery (TIRM) (TR: 8000 ms; TE: 95 ms; FoV: 300; FoV Phase: 100%; 36 slice; slice thickness 4mm; Base resolution: 448; Phase resolution: 75%);
- Axial T1-weighted 3D spoiled Gradient Echo (FLASH - Fast Low Angle Shot) (TR: 16ms; TE: 4.76 ms; FoV: 370; FoV Phase: 39.3%; 80 slice; slice thickness 2mm; Base resolution: 448; Phase resolution: 84%; Slice resolution: 93%);
- Axial T1-weighted 3D fat suppressed spoiled Gradient Echo (FLASH - Fast Low Angle Shot) (TR: 93ms; TE: 4.76 ms; FoV: 370; FoV Phase: 39.3%; 80 slice; slice thickness 2mm; Base resolution: 448; Phase resolution: 84%; Slice resolution: 93%);
- Sagittal T1-weighted 3D spoiled Gradient Echo (FLASH - Fast Low Angle Shot) (TR: 35ms; TE: 6.92 ms; FoV: 330; FoV Phase: 56.3%; 64 slice; slice thickness 2mm; Base resolution: 512; Phase resolution: 84%; Slice resolution: 81%).

NUMARIS/4 software (vers. Syngo MB A35) was used for images acquisition.

Images were transferred to an Apple workstation (OsiriX, Apple, v 3.0.2, 32 bit) for post-processing segmentation. This software has been already validated for post-processing of DICOM images generated by different diagnostic methods (CT, MRI, PET and PET-CT).

The images were evaluated by two different radiologists, with 5 and 2 years of breast MRI experience, respectively.

Prior to start the study, the two radiologists collectively agreed on the MRI segmentation modality and a previous training was performed on 1 exam which was not included in the study. They were blinded to the subject data and independently analyzed all the 20 breasts.
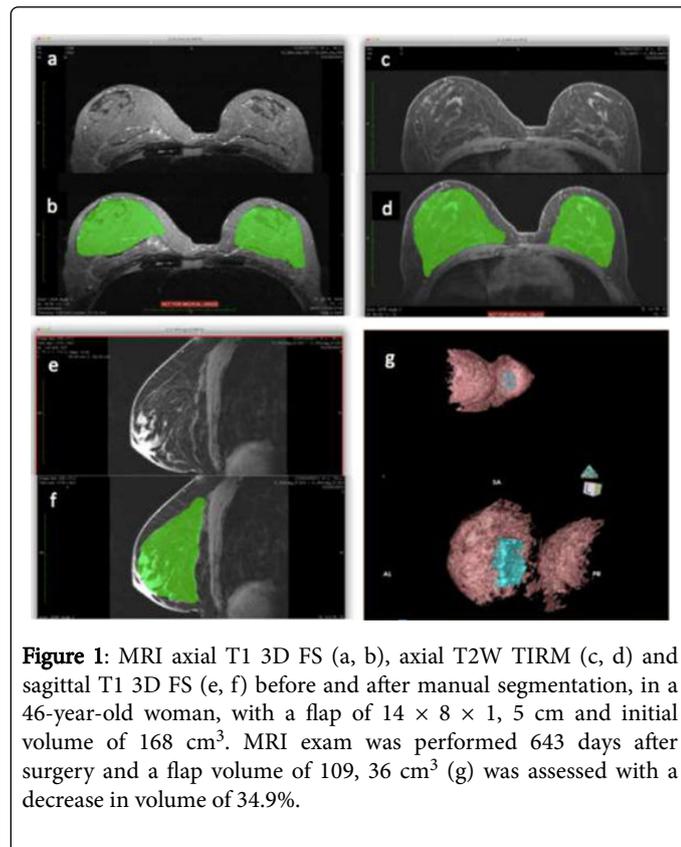
The segmentation could be considered as the delimitation of a perimeter and it was obtained for the breast and for the flap, manually drawing an area of interest on all the MRI single images, respecting the previously decided following criteria:

For breast segmentation, nipple and skin ventrally and pectoral muscles dorsally (pectoral muscles were not included in the breast volume assessment) were considered as anatomic borders;

For flap segmentation, the radiologists drew the area following the flap edges.

The segmentation was performed for each patient, for each breast and for each slice. The radiologists repeated the segmentation 5 times on the axial T2 weighted TIRM images, on axial T1 weighted 3D FS images and on sagittal T1 weighted 3D images (Figure 1a-1f).

After the segmentation, for each breast, flap volume (FV) and total volume (TV), which included both breast tissue and flap, were obtained through an automatic input of the OsiriX software, called ROI Volume (Figure 1g). Right and left FV and TV measurements required a mean time of 3 hours for each radiologist, for a total of 90 hours of work for each radiologist (3 hours × 10 exams × 3 sequences).

Figure 1: MRI axial T1 3D FS (a, b), axial T2W TIRM (c, d) and sagittal T1 3D FS (e, f) before and after manual segmentation, in a 46-year-old woman, with a flap of $14 \times 8 \times 1$, 5 cm and initial volume of 168 cm^3. MRI exam was performed 643 days after surgery and a flap volume of 109, 36 cm^3 (g) was assessed with a decrease in volume of 34.9%.

T-student test was performed to compare the averages of FV before mastopexy (measured during surgical intervention) and after mastopexy (measured on MRI sequences). Mean variability in FV was also evaluated.

To analyze the intra-observer and inter-observer variability, which correlate with the reproducibility of the segmentation, the mean value of FV (right and left) and TV measurements of the two different radiologists, were compared using T-student test and Pearson correlation test. T-student test was also carried out to evaluate the differences between the segmentations reported by the 2 readers for the three different MRI sequences. Statistical significance was set at P <0.05.
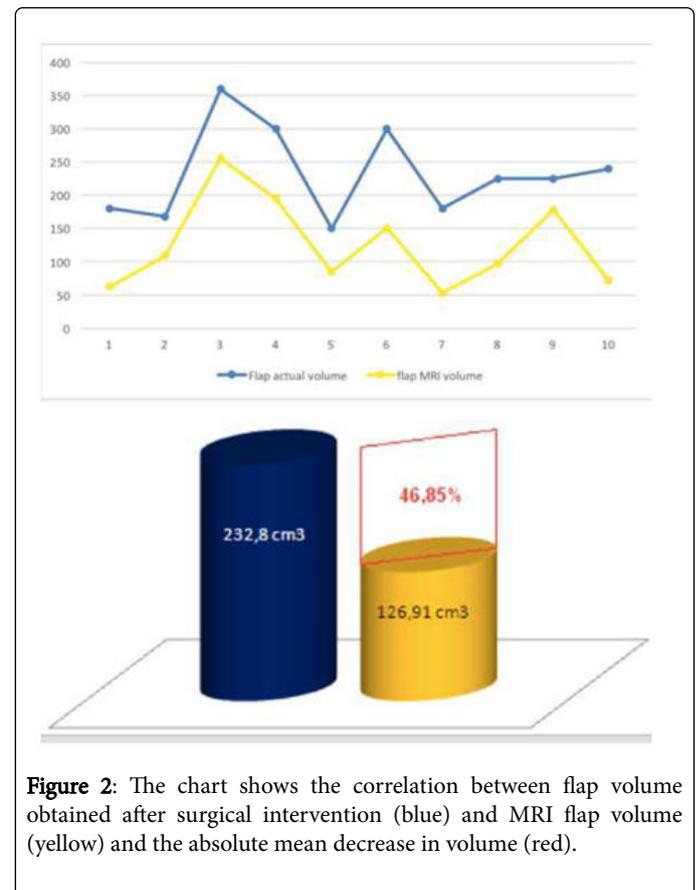All data analysis were processed using SPSS© statistical software program version 18.0.

Results

A total number of 10 patients with 20 breasts were enrolled in the study. No patient was excluded. All patients were female and in a good health status; the age ranged from 30 to 59 years (median value: 45 years) and the BMI ranged from 18 to 33. Six patients were in pre-menopausal and 4 patients were in postmenopausal.

Mastopexy was performed for each patient bilaterally, using AICAP flap for autologous augmentation.

There was a significant difference between the mean FV removed during surgical intervention (232.80 cm^3) and the mean FV measured on MRI sequences (138 cm^3) with a p value <0.05. An absolute mean decrease in volume of 46, 85% was observed (Figure 2).

Figure 2: The chart shows the correlation between flap volume obtained after surgical intervention (blue) and MRI flap volume (yellow) and the absolute mean decrease in volume (red).

Flap dimensions and volumes for all the patients are shown in the Table 1. T-student test demonstrated there was no significant difference in measurement of FV between the 2 readers for both sides (right flap with a p=0.1355 and left flap with a p=0.1518). Pearson test showed a positive correlation, with a ρ value between the 2 readers of 0.88 for left flaps and 0.90 for the right ones (Figure 3a and 3b).

The MRI segmentations of the same reader were not significantly different, with a p value of 0.987 for right flaps and 0.786 for left flaps. Pearson correlation value was 0.99 for both the flaps (Figure 3c and 3d).
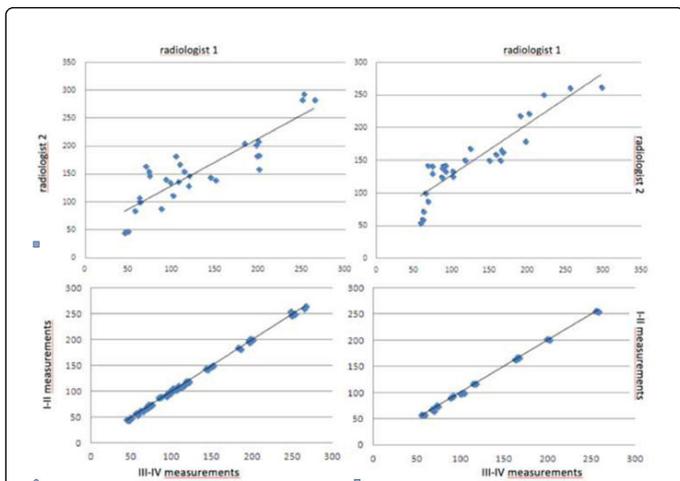
Figure 3: The charts show the inter- and intra-observer variability in segmentation for right and left flap, respectively.

The mean percentage of differences in segmentations between the 2 readers was 27.4% on the axial T2 weighted TIRM images, 27.2% on the axial T1 weighed FS images and 21% on the sagittal T1 weighed FS images (Figure 4).
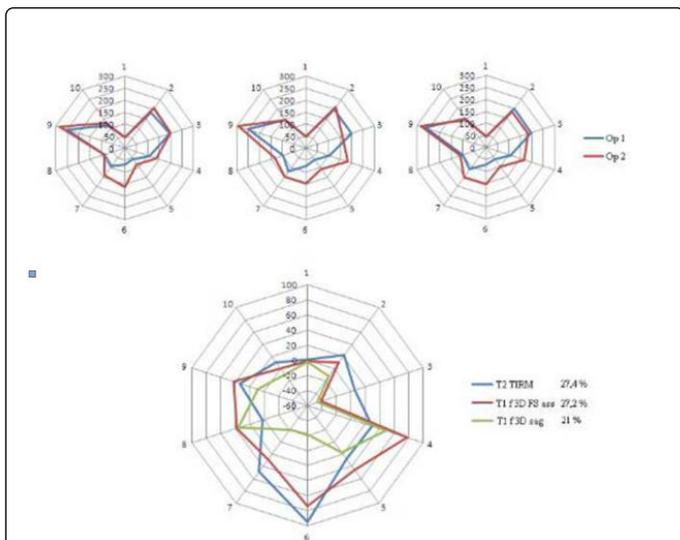

Figure 4: The charts show the mean percentage of measurement differences in axial T2W TIRM images, axial T1W FS images and sagittal T1W FS images and the correlation between the sequences and the percentages.

Both the readers agreed in choosing T1-weighted images as the best performing images.

Discussion

In breast surgery, breast volume assessment is a mandatory action for pre-operatory planning, in order to obtain optimal aesthetical result and to guide subsequent interventions such as breast asymmetry correction or addictive and reductive mastoplasty [9-18].

Information about pre-operative breast volume is fundamental in patients with massive loss of weight following bariatric surgery, who want to evaluate the option of free flap reconstruction. Bariatric surgery can cause irregularities of subcutaneous tissue and redundant skin. In these cases it is important to know the real breast volume to perform a correct flap elevation and to restore the proper volume and breast symmetry [1,3].

In international literature, the need to improve breast volume assessment and to identify an objective and reproducible technique has been expressed. Many of existing techniques have some limitations in cost, difficulty of performance and some of them are not always appreciated by patients [11,12]. For these reasons, despite the benefits that would result, their use is not accepted in the routine of plastic and reconstructive surgery.

The methods used for breast volume assessment include five categories, each one with some advantages and some disadvantages: anthropomorphic method [12,15]. Archimedean method, thermoplastic fusion, 3D laser scanner and MRI. The last one is usually used for benign from malignant breast lesions differentiation, but in literature, its application in volumetric assessment has also been shown [12,19-21].

Despite in the last decade an increase in using volume assessment before breast mastopexy has been shown, there is still not a preoperative routinely validated technique [12].

Our first goal was to evaluate the performance of MRI in flap volume assessment basing on its high sensibility and good specificity in giving morphological and functional information about normal and pathological tissue. The use of high field magnet (1.5T) and dedicated coils allow the contemporary study of both breasts with elevated spatial resolution. Moreover, 3D segmentation and breast visualization are useful tools in breast lesions identification and in breast volume assessment.

The images segmentation is currently used in breast MRI to isolate pathological tissue from normal glandular tissue. Three different segmentation methods have been described [12]: manual, semi-automatic and automatic method, which use algorithms such as FCM (Fuzzy C-Means), clustering and GVF (Gradient Vector Flow) snake.

In our study the manual method was used, for its broad accessibility. Our results showed that, after a minimum of 6 months, there was a significant volume reduction of the entire AICAP flap. This reduction could be due to different factors, such as flap ipo vascularization, as a consequence of principal vascular pedicle section, local ischemia with cellular apoptosis and post-surgical flogosis.

Despite these modifications, MRI manual segmentation of flap and breast tissue in bariatric patients who undergone bilateral mastopexy, has proved to be a reproducible method, due to a low intra- and inter-observer measurements variability, demonstrated by the higher agreement between the two radiologists who performed the segmentations.

Even more, we wanted to identify the best non-enhanced MRI sequence in volume calculation.

In usual post-surgical examination, T2-weighted images have been used to reveal the presence of post-surgical fluid collection and T1-weighted images have been evaluated because of their capability to identify magnetic susceptibility artifacts, determined by acusector cut, in order to easily outline the edge between AICAP flap and breast

tissue. T1-weighted images have a higher intrinsic resolution power, allowing performing thinner slice.

For these reasons, sagittal T1-weighted FLASH 3D turned out to be the most advantageous sequences for image segmentation and volume 3D reconstruction. Furthermore, both the readers agreed in choosing T1 as the best performing sequence, because the magnetic susceptibility artifacts allowed an easier segmentation of the flap, and, consequently, a better identification of the edge between flap and breast. The measurements of segmentation on sagittal T1-weighted FLASH 3D showed the lower intra-and inter-observer disagreement.

To our knowledge this is the first study which reports MRI performance in breast volume assessment after mastopexy using AICAP flap that is largely employed in our institution for breast augmentation in patients who underwent bariatric intervention.

In this study the main limitations are the low number of patients and the large time variability between post-bariatric mastopexy and MRI examination. Moreover, the absence of a pre-operative MRI exam for each patient should be considered, which would allow a better correlation between the pre-operative and post-operative breast volume. The strength points are the blind segmentation execution followed by good reader's agreement, the use of a non-invasive, radiation free and non-contrast technique for volume assessment and the use of a standardized protocol for all exams, reducing MRI acquisition time.

Conclusion

In conclusion, we believe that the use of MRI in flap volume assessment, in particular using T1-weighted sequences, could be a helpful tool to calculate the variability of flap volume after mastopexy, providing quantitative information potentially useful for surgeons to obtain the best aesthetic results.

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