

Menstrual Cycle-Related Fluctuations in Breast Volume Measured Using Three-Dimensional Imaging: Implications for Volumetric Evaluation in Breast Augmentation



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Abstract

Background Breast volume is a key parameter of breast measurement in breast augmentation. However, the correlation between menstrual cycle phases and variation in breast volume has not been well studied.

Methods Young female patients with regular menstrual cycles underwent eight three-dimensional imaging scans during a single menstrual cycle from November 2017 to January 2018. Breast volumetric difference at each time-point and basic breast volume were measured for each subject. Preovulatory phase and postovulatory phase values were compared using an unpaired *t* test. A Pearson's linear correlated analysis was performed to identify the correlation between the basic breast volume and maximum range of breast volumetric difference during the menstrual cycle. **Results** Thirteen patients (26 breasts) met the inclusion criteria. During the menstrual cycle, the breast volumetric difference showed first a rising trend followed by a fall. A significant difference in the breast volumetric difference between the preovulatory phase and postovulatory phase (-19.6 ± 2.1 ml pre-ovulation vs. -6.9 ± 3.3 ml post-ovulation, $p = 0.002$) was noted. There was a positive linear association between breast volume and maximum

range of breast volumetric difference when a Pearson correlation was used ($r = 0.45$, $p = 0.021$).

Conclusions The breast volume fluctuates during the menstrual cycle, and there is a significant difference between the preovulatory phase and postovulatory phase for breast volumetric change. The influence of the menstrual cycle on breast volume should be taken into consideration by plastic surgeons performing breast augmentation.

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Keywords Menstrual cycle · Breast volume · Three-dimensional imaging · Mammoplasty

Introduction

Breast volume has long been utilized as a key index of breast measurement for breast plastic surgery, especially for breast augmentation [1]. To achieve optimal aesthetic results, correct quantification of breast volume is imperative in both preoperative surgical planning and postoperative evaluation of outcomes during follow-up [2]. Many factors, however, including respiration [3], posture [4] and breast shape [5] can cause variability in breast volume measurements.

In premenopausal women, normal breast tissue responds to the fluctuation of endogenous hormones showing structural and morphological changes during the menstrual cycle (MC) [6]. Previous studies focused on analyzing the changes in fibroglandular tissue volume and breast density during the MC using magnetic resonance imaging (MRI) to find some relationship between breast tissue changes and

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breast cancer [7, 8]. Few studies have, however, paid attention to the fluctuations in breast volume during the MC and the effect of that on breast plastic surgery. Furthermore, with the MRI technique, the breast is scanned in a prone position, which is not the most accurate way for plastic surgeons to do inspection, resulting in measuring error for the breast volume [9].

In recent years, the three-dimensional (3D) scanning technique has gained increasing popularity in plastic surgery for its convenience to perform 3D analysis of the breast [10]. Thus, given the paucity of data in the breast plastic surgery literature on breast volume changes during MCs, a study was designed to evaluate the correlation of MC phases and breast volume measured using the 3D imaging technique. This study had three main objectives. First, to describe the variation of breast volumetric difference in one MC. Second, to determine whether there is significant difference on the breast volumetric difference during the MC. Third, to establish whether there is a correlation between basic breast volume and maximum range of breast volumetric difference during the MC.

Patients and Methods

Patients Enrollment

The protocol of this study was approved by the Institutional Ethics Committee and conducted in accordance with the guidelines set forth in the Declaration of Helsinki [11]. The patients were recruited through advertisement from November 2017 to January 2018. The inclusion criteria for participants were as follows: (1) age between 18 and 30 years as baseline estrogen and progesterone levels are highest in this population and begin to decline as a woman approaches her thirties [12]; (2) regular menstrual cycle—about the same length every month; (3) no significant changes in body weight during study. The exclusion criteria were: (1) prior breast surgery; (2) congenital breast deformities; (3) significant breast ptosis (Regnault type 2 or higher); (4) breast with nodules diagnosed by ultrasonography; (5) pregnancy at the time of this study; (6) taking contraceptive pills or receiving any hormonal therapy. Participants were required to complete a questionnaire for collection of demographic information such as height, weight and chest circumference.

Three-Dimensional Scanning

All participants underwent three-dimensional breast scanning (JRCB-D; Jirui, Beijing, China; accuracy, ≤ 0.1 mm) using our previously validated protocol [13]. In brief, the patient was asked to stand upright with her back leaning

against a wall and her hands placed on her anterior suprailiac spine. She was instructed to hold her breath at the end of normal exhalation. A PLY formatted file was used to store both the 3D surface structure and the surface color. The scanning frequency was eight times monthly with an interval of 3–5 days between scanning sessions. For each subject, the first scanning session took place on the first day of menstruation.

Breast Volumetric Difference and Basic Breast Volume Measurements

The breast shape on the first day of menstrual bleeding was referred to as the initial scan. The breast volumetric difference was defined as the volume deviation between subsequent scans and the initial scan. The volumetric difference was measured using the Geomagic Studio 12 software (Geomagic Solutions, Morrisville, NC, USA) according to a method previously proposed [14]. Briefly, two breast scans were best-fit aligned in the software. Two identical cylinders were created along the breast border with the breast surface as the dome. The volumetric discrepancy between the two cylinders was regarded as the breast volumetric difference. For each patient, the state of the smallest breast during the menstrual cycle was selected for measurement and was defined as the basic breast volume. Breast volume was measured according to a method introduced by Kovacs et al. [15]: After the anatomic border of the breast was delineated, the breast region inside it was removed. Then, the simulated chest wall template was constructed via the “curvature-based filling” function. Breast volume was computed by Boolean operation.

Breast Volumetric Difference Data Analysis

Based on the time of ovulation, the MC can be divided into two phases: follicular and luteal. To examine the fluctuations in breast volumetric difference change during the menstrual cycle in detail, the menstrual cycle was divided into 5 periods (T0 = onset of menses, T1 = early follicular phase, T2 = late follicular phase, T3 = early luteal phase, T4 = late luteal phase). The average breast volumetric difference in each period was calculated, and a figure of the changing trend was drawn. Based on obstetric studies, the hormone levels fluctuate during the menstrual cycle. More specifically, around 7 days before ovulation during the late follicular phase a rise in estrogen induces ovulation, whereas 8 days after ovulation the corpus luteum releases peak levels of progesterone which gradually decrease until the end of the menstrual cycle [16]. To identify whether there is a significant breast volumetric difference change during a single MC, we assumed that the midpoint of the menstrual cycle is the day of ovulation. The preovulatory

phase consists of 7 days before ovulation, and the postovulatory phase from the eighth day of post-ovulation to the end of the cycle. The breast volumetric difference data during the preovulatory phase and during the postovulatory phase were selected. The definition of maximum range of breast volumetric difference was equal to the maximum of breast volumetric difference minus the minimum of breast volumetric difference in a single MC.

Statistical Analysis

The data of breast volumetric difference were presented as mean \pm SEM. Preovulatory phase and postovulatory phase values were compared using an unpaired *t* test. A Pearson correlated analysis was performed to identify a linear correlation between the basic breast volume and the maximum range of breast volumetric difference during the MC, and linear regression was used to define the linear relationship. SPSS program version 16 (SPSS, Chicago, IL, USA) was used for the above data analysis. Differences were considered statistically significant when the *p* value was less than 0.05.

Results

Patient Characteristics

A total of 13 patients (26 breasts) participated in the study. Patient age, body mass index (BMI), bust size, under bust size and menstrual cycle length are listed for each patient in Table 1. The mean age of patients was 24.7 years, ranging from 21 to 28 years. The mean BMI was

20.9 ± 1.21 kg/m² (range 18.8–22.4). The mean menstrual cycle was 29.8 days, ranging from 27 to 35 days.

Breast Volumetric Difference Fluctuation Trend in a Single Menstrual Cycle

The breast volumetric difference change showed first a rising trend followed by a fall in a menstrual cycle. Starting on the first day of the menstrual cycle, that is the onset of menses, the breast volumetric difference first decreased during the follicular phase and then increased during the luteal phase (Fig. 1). The breast volume reached a minimum around the time of ovulation and a maximum around the end of the menstrual cycle.

Breast Volumetric Difference Comparison Between the Preovulatory Phase and Postovulatory Phase

A significant difference in the breast volumetric difference was observed between the preovulatory phase and the postovulatory phase (-19.6 ± 2.1 ml pre-ovulation vs. -6.9 ± 3.3 ml post-ovulation, *p* = 0.002) (Fig. 2).

Correlation Between Basic Breast Volume and Maximum Range of Breast Volumetric Difference

A positive linear association between basic breast volume and maximum range of breast volumetric difference was evident when a Pearson correlation was used (*r* = 0.45, *p* = 0.021) (Fig. 3). The breast volumetric difference was defined by the following equation: Maximum range of breast volume difference = (basic breast volume \times 0.08) + 24.5.

Table 1 Patient demographics

Patient no.	Age (years)	BMI (kg/m ²)	Bust size (cm)	Under bust size (cm)	Menstrual cycle (days)
1	28	20.9	84.5	75.0	32
2	26	19.5	76.0	68.0	27
3	23	21.5	82.5	74.5	30
4	25	21.8	89.9	80.5	28
5	26	18.8	79.5	71.0	29
6	27	20.6	84.5	74.5	28
7	22	21.5	87.0	77.0	29
8	23	21.5	81.0	70.0	35
9	26	19.9	81.0	70.5	28
10	25	22.4	93.5	80.5	30
11	27	22.0	88.0	76.8	27
12	23	19.0	80.0	68.5	29
13	21	22.0	88.0	77.5	35

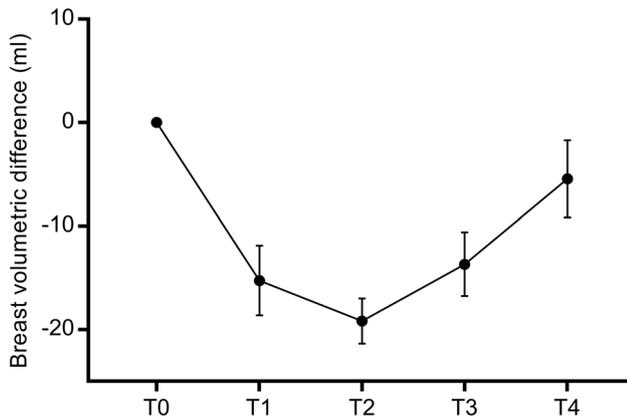


Fig. 1 The changes in average breast volumetric differences in a single menstrual cycle. T0 = onset of menses, T1 = early follicular phase, T2 = late follicular phase, T3 = early luteal phase, T4 = late luteal phase. *BVD* breast volumetric difference

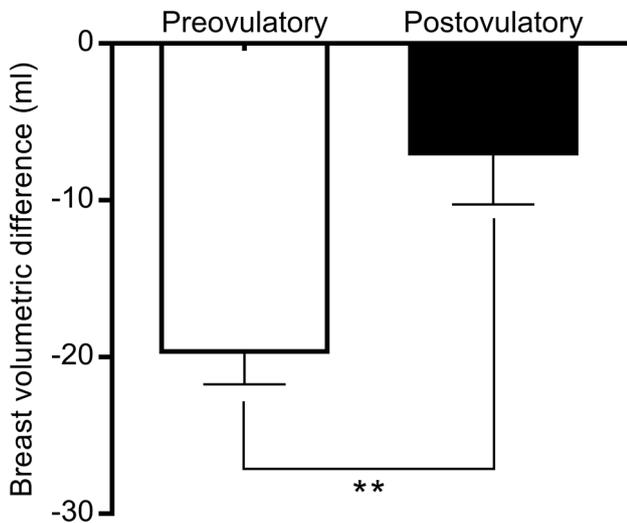


Fig. 2 Comparison of the breast volumetric differences between preovulatory phase and postovulatory phase. *BVD* breast volumetric difference

Discussion

Our study highlights that the breast volume is significantly smaller in the preovulatory phase when compared with that in the postovulatory phase of the menstrual cycle. In general, the breast volume first decreased and then increased from the onset of menses to the end of menstrual cycle. Hussain et al. [17] studied the breast volume and its variation during the menstrual cycle using MRI and found that the breast volume was at a minimum mid-cycle and increased by up to 40% in the week before menstruation. Our results are consistent with that conclusion. Their study, however, focused on three test sessions during a single menstrual cycle for each subject, making it more difficult to state the trend of breast volume change. In our study,

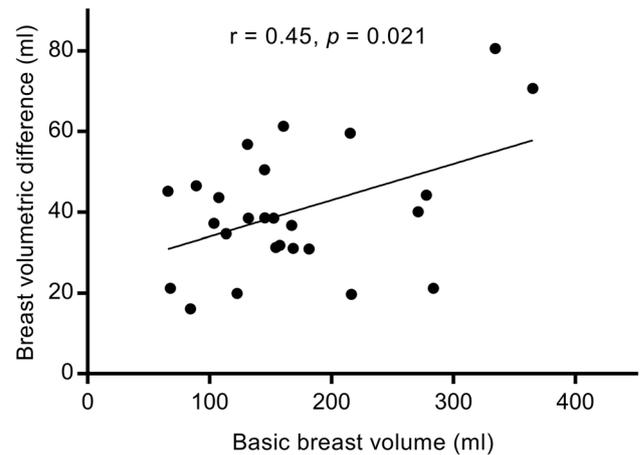


Fig. 3 A positive linear correlation between basic breast volume and maximum range of breast volumetric differences during one menstrual cycle. Maximum range breast volumetric difference = maximum breast volumetric difference – minimum breast volumetric difference. *BVD* breast volumetric difference

each participant received eight sessions of 3D breast imaging, and therefore, the results better reflect the trend in breast volume change.

Additionally, we used a 3D breast imaging technique to calculate the breast volumetric difference and describe the change in breast volume during a single menstrual cycle. Compared with MRI, 3D imaging is quicker and more affordable. Importantly, the breast is scanned with the patient in the upright position, which is similar to the way plastic surgeons inspect breasts. Additionally, a recent study showed that there is high standard deviation in terms of percentage of breast volume when using 3D imaging to calculate the absolute breast volume [18]. Thus, in addition to using the 3D imaging technique, we used breast volumetric difference, a more accurate index, to measure the breast volume change during the menstrual cycle [14]. The actual breast volume cannot be measured due to an inability of a 3D scanner to scan the posterior border of the breast. Aligning the surface of the anterior chest wall in each scan with the scan taken on the first day of the menstrual cycle to directly acquire the breast volumetric difference improves accuracy and repeatability.

The estrogen and progesterone levels in premenopausal women fluctuate over the course of the menstrual cycle. During the follicular phase, serum estrogen levels rise in parallel to the growth of a follicle size and reach a peak on the day of ovulation. After ovulation, the corpus luteum becomes a transient endocrine organ that predominantly secretes progesterone. Progesterone and estradiol reach a peak serum level 8 days post-ovulation [19]. Ramakrishnan et al. [6] examined the breast tissue from premenopausal women and found that there was increased mitotic activity in the breast lobules and extensive stromal

edema in the late luteal phase compared to the follicular phase. This may help explain why the breast volume was much larger in post-ovulation than in pre-ovulation. The breast density change during the menstrual cycle has been previously studied as it is an independent risk factor for breast cancer [20, 21]. Awareness of how breast volume changes during the menstrual cycle is, however, also very significant for both fat grafting and implant-based breast augmentation. With the case of breast fat grafting, volume retention rate is an important parameter to evaluate the effectiveness of various techniques. Studies utilizing the same method such as a 3D measurement system or MRI to assess volume gain relative to graft volume have shown varying results [22]. Our study indicates that the menstrual cycle significantly influences breast volume change. It is necessary to consider this factor when measuring the breast volume for breast plastic surgery. Additionally, one previous study proved that breast volume gradually diminishes due to tissue detumescence and breast tissue attenuation or atrophy after augmentation mammoplasty [23]. However, the above study also neglects to consider the effect of the menstrual cycle during the follow-up. The conclusion should be considered more cautiously.

In our study, we also found that there was a positive correlation between basic breast volume and the maximum range of breast volumetric difference during the menstrual cycle, which was consistent with the former study that found that breast size correlates with endogenous hormone levels [24]. Larger breast volumes are more susceptible to hormone fluctuation during the menstrual cycle. The subjects in our study were all slim Asian women with relatively small breast sizes, so we saw a small breast volumetric difference (-19.6 ± 2.1 ml pre-ovulation vs. -6.9 ± 3.3 ml post-ovulation) between preovulatory and postovulatory phase. This positive correlation, however, may predict that in the case of patients with bigger breast sizes, the difference will be bigger, which would be more noticeable to plastic surgeons. Based on this, the results can be generalizable to other populations.

Our study does, however, have limitations. The subject number was small, which might be insufficient to show a strong association between breast volume and breast volumetric difference change during the MC. On the other hand, we did not measure the hormone levels at the time when the subjects received the 3D scanning, and, hence, could not discuss the relationship between hormone changes and breast volumetric change.

Conclusions

Breast volume fluctuates during the menstrual cycle, and we note a significant difference between the preovulatory and postovulatory phase for breast volumetric difference. The influence of the menstrual cycle on breast volume should be taken into consideration by plastic surgeons performing breast augmentation.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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