Original Article

Weight to volume conversion: an easy and practical breast volume estimation

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Background: Accurate breast volume estimation is essential for symmetrical breast reconstruction. Easy conversion of the weight of the resected breast tissue to volume could result in precise volume measurements. This study aimed to introduce the use of a mathematical constant (k) to estimate the breast volume from the weight.

Methods: Eighty-nine female patients with breast cancer who underwent surgery at King Chulalongkorn Memorial Hospital between September 2010 and February 2011 were enrolled in this prospective study. The mammographic density of each patient was classified according to the breast imaging reporting and data system (BI-RADS) into groups a, b, c, and d. The breast density number and mathematical constant (k) were calculated, and the data matched. This technique was validated by comparing the measured and calculated volumes.

Results: Sixty-six, 22, and 1 patients underwent total mastectomies (TMs), skin-sparing mastectomies (SSMs), and nipple-sparing mastectomies (NSMs), respectively. The breast densities were 1.0629, 1.1545, and 1.2233 g/mL, and the constant number (k) was 0.9409, 0.8662, and 0.8175 for BI-RADS a, combined BI-RADS b and c, and BI-RADS d, respectively. The validation process showed no significant differences between the measured and calculated volumes [95% confidence interval (95% CI)]. The correlation coefficient (r) was 0.984.

Conclusions: Accurate breast volume estimation is a key factor in achieving symmetry in breast reconstruction. Combining existing data, including the weight of the resected breast tissue and mammographic density findings, an easy and accurate method to calculate the resected breast volume was introduced.

Keywords: Mammographic density; breast density; water-displacement technique; Archimedes principle; constant number

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Introduction

Background

Immediate or delayed breast reconstruction should be an option for every patient undergoing mastectomy. In certain circumstances, delayed reconstruction may be a better option. Generally, compared to delayed repair, immediate breast reconstruction has several benefits, including psychological advantages after mastectomy with a reconstructed breast and improved cosmetic outcomes since the three-dimensional breast skin envelope is preserved. A quicker return to activity after immediate breast reconstruction also helps athletes avoid the potentially humiliating scenario of loose external implants while working out (1).

Rationale and knowledge gap

A widely used density classification scheme for evaluating the findings of mammography investigations is the breast imaging reporting and data system (BI-RADS): a score of "a" indicates the breasts are almost entirely fatty; a score of "b" indicates there are scattered areas of fibroglandular density; a score of "c" indicates the breasts are heterogeneously dense, which may obscure small masses; a score of "d" indicates the breasts are extremely dense, which lowers the sensitivity of mammography (2-5). Accurate breast volume estimation is a key factor in achieving symmetry in all types of breast reconstruction. The weight of the resected breast tissue is routinely measured. The resected breast volume can be calculated using the water displacement method (Archimedes principle) (6) or a sizer (7). However, this method is time-consuming.

Highlight box

Key findings

- We demonstrated that the application of the breast density number or constant number (k) correlates with breast density and is a useful alternative for assessing breast volume.

What is known, and what is new?

- Accurate breast volume estimation is a key factor in achieving symmetry in breast reconstruction.
- Combining existing data, including the weight of the resected breast tissue and mammographic density findings, we introduced an easy and accurate method to calculate the resected breast volume.

What is the implication, and what should change now?

- By utilizing our method for accurate breast volume estimation, symmetry can be achieved in all types of breast reconstruction. However, further multicenter, large-volume studies are necessary to validate our findings.

Objective

Combining existing data, such as the weight of the resected breast tissue and mammographic density findings, an easy and accurate method to calculate the resected breast volume can be achieved. This study aimed to evaluate breast density and the frequency of breast patterns in patients using mammographic densities. We present this article in accordance with the STROBE reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-23-262/rc).

Methods

Patients

Eighty-nine female patients who were diagnosed with breast cancer using mammography and underwent mastectomy at King Chulalongkorn Memorial Hospital between September 2010 and February 2011 were enrolled in this prospective descriptive study. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The Institutional Review Board (IRB) of the Faculty of Medicine at Chulalongkorn University in Bangkok, Thailand, approved the study (IRB number 338/53). Written informed consent was obtained from all the patients. Demographic data and medical records, including the weight of the resected breast tissue, were assessed. Participants were classified as clinical stage 0, I, or II according to the American Joint Committee on Cancer (AJCC) staging system (8,9) with a primary tumor of less than or equal to T2. All patients underwent mastectomy such as skin-sparing mastectomy (SSM), nipple-sparing mastectomy (NSM), or total mastectomy (TM). Patients who received neoadjuvant radiotherapy were excluded.

Breast tumor measurements

The distributions of the clinical tumor sizes and mammographic densities were obtained based on the BI-RADS density category to determine the frequencies of the patients' breast patterns. The BI-RADS terms for breast density were based on the following findings: (I) BI-RADS a, the breasts are almost entirely fatty; (II) BI-RADS b, there are scattered areas of fibroglandular

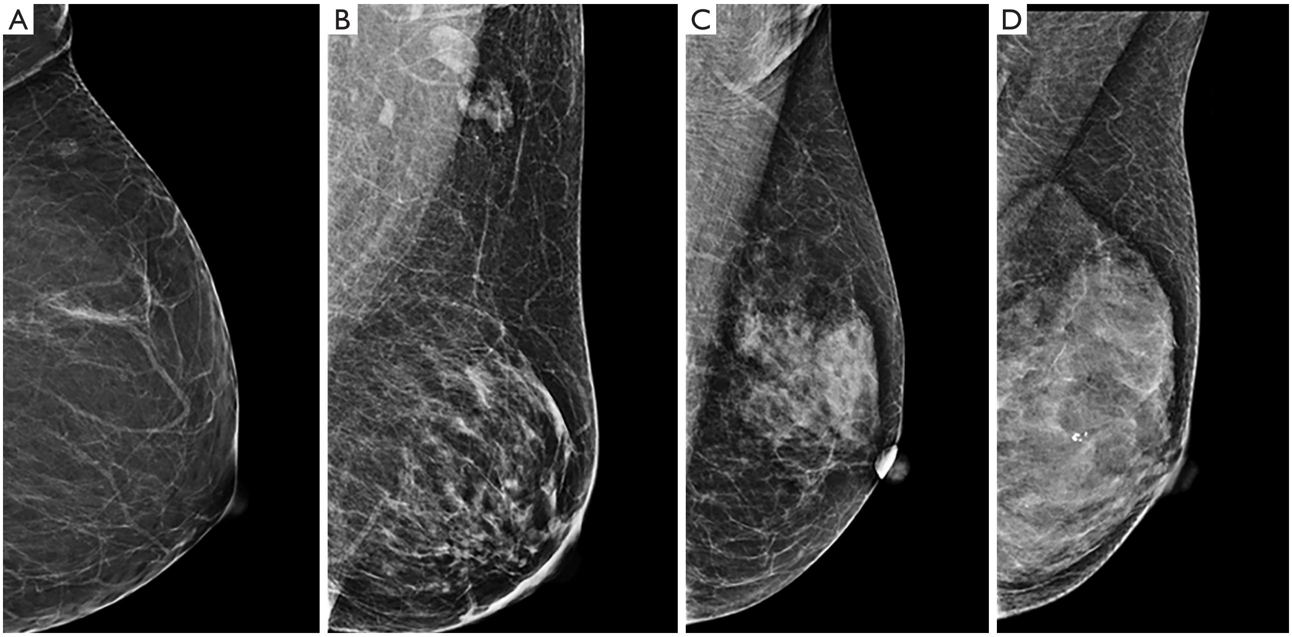

Figure 1 Mammographic appearance determines the categorization of breast densities. The BI-RADS established by the ACR classifies breast density into four groups: (A) the breasts are almost entirely fatty (BI-RADS a), (B) there are scattered areas of fibroglandular density (BI-RADS b), (C) the breasts are heterogeneously dense, which may obscure small masses (BI-RADS c), and (D) the breasts are extremely dense, which lowers the sensitivity of mammography (BI-RADS d). BI-RADS, breast imaging reporting and data system; ACR, American College of Radiology.

density; (III) BI-RADS c, the breasts are heterogeneously dense, which may obscure small masses; and (IV) BI-RADS d, the breasts are extremely dense, which lowers the sensitivity of mammography (*Figure 1*) (2-5). The mammographic data were classified by a single radiologist.

After the removal of the axillary lymph nodes, the perioperative breast mass specimen was weighed digitally and quantified using Archimedes' method of water displacement. Water was placed in a 2-liter container and set on a horizontal plane. The breast tissue was completely immersed to prevent compression of the specimen. This procedure was performed by a well-trained plastic surgery resident. The breast density was calculated using the following formula: density (g/mL) = mass (g)/volume (mL).

The mathematical constant (k), which is the reciprocal of the breast density (1/breast density), was calculated. Data from the mammographic density findings and the corresponding constants were matched.

Statistical analysis

Patient parameters such as age, body mass index (BMI), tumor size, and breast density were reported as the mean ± standard deviation (SD), median, and range. The paired-sample *t*-test was used for group analysis. SPSS for Windows (version 15.0; SPSS, Inc., Chicago, IL, USA) was used for the data analysis. The water displacement method and the formula using the mathematical constant (k) were compared to determine the volume of each resected breast tissue. The mean volumes calculated using the two methods were compared using the mean percentage difference, and group analysis was performed using P values and 95% confidence intervals (95% CIs).

Results

Patient characteristics

Of the enrolled 89 patients, 66 underwent TM, 22 underwent SSM, and 1 underwent NSM. Demographic data and medical parameters, including the weight of the resected breast tissue, were recorded. Of the 89 included patients, 15% (n=13) were <40 years old, and 8% (n=8) were ≥70 years. The median age of the patients was 53 years (range, 26–82 years) (*Table 1*). The median BMI

Table 1 Summary of patients' demographics

Factor	Values
Age (years)	
Median [range]	53 [26–82]
20–29	2 (3%)
30–39	11 (12%)
40–49	21 (24%)
50–59	25 (28%)
60–69	22 (25%)
≥70	8 (8%)
BMI (kg/m^2)	
Median [range]	24 [17–43]
<19	2 (2%)
19–24.9	58 (66%)
25–29.9	20 (22%)
≥30	9 (10%)
Menopausal status	
Pre-menopause	31 (35%)
Post-menopause	58 (65%)
Side of breast cancer	
Right	48 (54%)
Left	41 (46%)
Histology	
Invasive ductal carcinoma	71 (80%)
Invasive lobular carcinoma	1 (1%)
DCIS	8 (9%)
Invasive papillary carcinoma	1 (1%)
Invasive mucinous carcinoma	2 (2%)
Fibronodular	1 (1%)
Mixed type	5 (6%)
Tumor size (cm)	
Mean	2.69
Median [range]	2.5 [0.4–5]
<2	30 (34%)
2–5	59 (66%)
Type of operations	
TM	66 (74%)
SSM	22 (25%)
NSM	1 (1%)
BI-RADS density category	
Fatty (BI-RADS a)	5 (6%)
Scattered fibroglandular (BI-RADS b)	20 (22%)
Heterogeneous dense (BI-RADS c)	47 (53%)
Extremely dense (BI-RADS d)	17 (19%)

BMI, body mass index; DCIS, ductal carcinoma in situ; TM, total mastectomy; SSM, skin-sparing mastectomy; NSM, nipple-sparing mastectomy; BI-RADS, breast imaging reporting and data system.

was 24 kg/m^2 (range, 17–43 kg/m^2). Most patients were postmenopausal (65%), and all 89 underwent breast cancer surgery. Forty-eight (54%) and 41 (46%) patients underwent surgeries on the right and left sides, respectively. Most patients with breast cancer had invasive ductal carcinoma (n=71, 80%). Ductal carcinoma in situ (DCIS) was detected in 9% of patients; 11% had mixed-type carcinomas, namely, invasive mucinous carcinoma, invasive lobular carcinoma, invasive papillary carcinoma, and fibronodular carcinoma. The tumors were classified according to the AJCC staging system as T1 (<2 cm) and T2 (2–5 cm), with a mean tumor size of 2.69 cm. Operative procedures included TM, SSM, and NSM in 66 (74%), 22 (25%), and 1 (1%) patients, respectively. The mammographic densities classified according to the BI-RADS are shown in *Table 1*.

Tumor volume estimation

The mean and SD of breast density and the constant number in each group of mammographic density from all operations are listed in *Table 2*. BI-RADS a (fatty breasts) had the lowest mean breast density, whereas BI-RADS d (extremely dense) had the highest density. The mean densities of the BI-RADS b and c groups were similar; therefore, only three groups of mammographic density were classified as BI-RADS a, combined BI-RADS b and c, and

Table 2 Mean volume by water-displacement method (Archimedes principle) and constant number (k) application with percentage of mean volume difference and group analysis

Operation	BI-RADS density category	Number of patients	Mean breast density (± SD), g/mL	Constant number (k)	Mean volume by measurement, mL	Mean volume by constant number (k)	Mean percentage difference (± SD)	P value
All operations	BI-RADS a	5 (6%)	1.0629 (±0.0982)	0.9409	663.2	628.334	7.4910 (±3.4873)	0.4695
	BI-RADS b and c	67 (75%)	1.1545 (±0.1750)	0.8662	549.0103	541.7763	9.6057 (±10.2957)	0.1312
	BI-RADS d	17 (19%)	1.2233 (±0.2275)	0.8175	410.4706	391.6465	12.2565 (±10.3866)	0.1914

BI-RADS, breast imaging reporting and data system; SD, standard deviation.

BI-RADS d. Breast density and constant number (k) from all operations classified by mammographic density are listed in *Table 2*. The correlation coefficient (r) was 0.984.

In the validation process, the mean weights of the water displacement method and method using the mathematical constant (k) formula were not significantly different (P>0.05; 95% CI: 0.1312–0.4695). The lowest mean percentage difference was 7.4910 for BI-RADS a, and the highest mean percentage difference was 12.2565 for BI-RADS d.

Discussion

Key findings

In this study, we aimed to demonstrate the application of the breast density number or constant number (k) to assess breast volume. We found that a constant number (k) correlates with breast density and is a useful alternative for assessing breast volume.

Comparison with similar research

Immediate breast reconstruction has many benefits, including the prevention of additional surgeries. This procedure is performed once the mastectomy is completed to eliminate the risks associated with subsequent surgeries. In addition, avoiding an interim period characterized by mammary deformity after mastectomy can have psychological benefits (10-13).

Several types of surgery can be performed for breast reconstruction, including implant/expander, autologous tissue, or implant/expander plus autologous tissue. Each method has its advantages and disadvantages. Implant breast reconstruction is a relatively simple and quick procedure with no donor site morbidity. The hospital stay is generally short, and the cosmetic results are satisfactory. However, it is only suitable for patients with small breasts and minimal or no ptosis (13). For patients with large breasts, autologous tissue or implant/expander plus autologous tissue breast reconstruction is more suitable (14,15).

Accurate measurement of breast volume is a key factor for achieving symmetry in all types of breast reconstruction. Many methods have been proposed, including water displacement (16), air displacement (17), casting (18), tissue expanders (19), anthropomorphic measurements (20), and biostereometric analyses (21). Several commercial breast-volume measurement products are available (22,23). Although these sophisticated methods are safe and relatively easy to use, they are add-on procedures and expensive. The proposed approach offers several practical advantages. Breast reconstruction in women with cancer has almost always been conducted following mammography (24). According to Baldwin *et al.* (25), the average breast density after 40 consecutive bilateral breast reductions was 0.95 g/mL. Breast tissue density varied from 0.8 to 1.2 g/mL. We divided our enrolled patients into three different mammographic density subgroups based on the BI-RADS density category to calculate breast tissue density more accurately. The weight of the resected breast tissues was measured routinely. In 2017, Lee *et al.* (26) conducted a study involving 276 women who underwent breast reconstruction surgery. They devised four equations linked to mammographic density, categorized into four groups (BI-RADS a to d). These equations hold potential value for breast reconstruction following mastectomy, and they are as follows: BI-RADS a: volume = 1.218 × breast weight + 7.45; BI-RADS b: volume = 1.036 × breast weight + 10.36; BI-RADS c: volume = 0.969 × breast weight − 7.47; BI-RADS d: volume = 0.871 × breast weight − 14.13.

For a practical example, consider the case of a 40-year-old female diagnosed with DCIS of the right breast. She underwent NSM, sentinel lymph node biopsy, and breast reconstruction using a silicone implant. Her mammographic

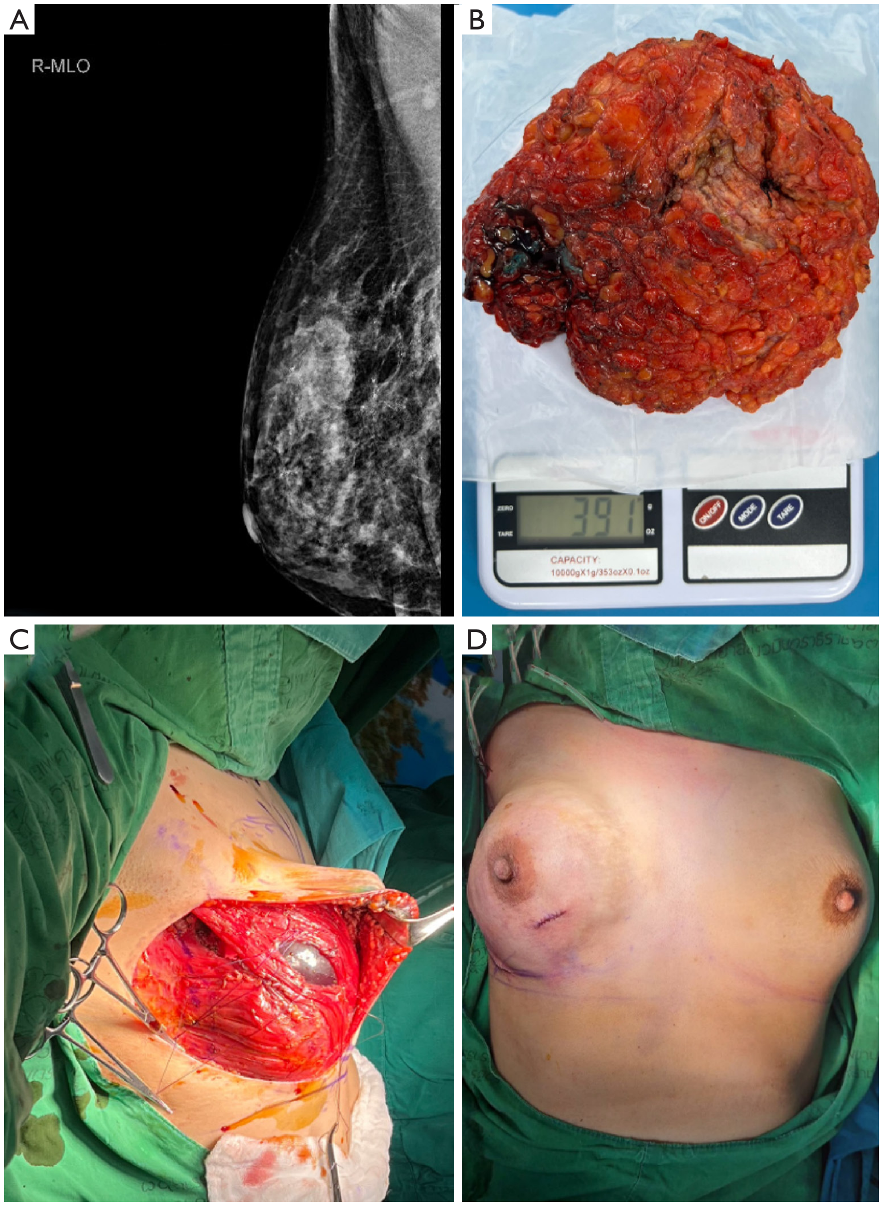

Figure 2 This case study involves a 40-year-old female diagnosed with ductal carcinoma in situ of the right breast. Her treatment included a nipple-sparing mastectomy, sentinel lymph node biopsy, and breast reconstruction utilizing a silicone implant. (A) Her mammographic density is categorized as BI-RADS d. (B) The weight of the breast tissue without axillary lymph nodes was 391 g. (C,D) After performing calculations using the constant (k), the calculated volume was found to be 319.64 mL. Then, a 325 mL breast implant was chosen for the breast reconstruction procedure. BI-RADS d, the breasts are extremely dense, which lowers the sensitivity of mammography. BI-RADS, breast imaging reporting and data system.

density was categorized as BI-RADS d. The constant (k) was determined to be 0.8175, and the breast weight, excluding the lymph nodes, was measured at 391 g. Consequently, the calculated volume was found to be 319.64 mL. However, to ensure accuracy, the water-displacement method was employed, yielding a volume of 359 mL. Consequently, there existed a discrepancy of approximately 10.96%. Subsequently, she underwent breast reconstruction with a 325 mL silicone implant (*Figure 2*). Moreover, when applying the calculation according to Lee *et al.*'s equation for BI-RADS d, the derived volume was 326.43 mL. This results in a difference of about 9.07%.

In this study, we measured the correlation coefficient to assess the degree of association between the weight of breast tissue and the volume of excised breast tissue, using both the water-displacement method and the calculation using the constant (k). This evaluation was conducted across various mammographic density categories. The calculated correlation coefficient (r) was 0.984, signifying a remarkably robust and positive linear relationship between the two variables under consideration.

Strengths and limitations

By combining these existing data, a considerably easy and accurate method to calculate the resected breast volume can be developed. Nonetheless, certain limitations in this study should be acknowledged. The small number of patients enrolled from a single center could be considered a limitation. The outcomes of the study could be uniquely tied to the patient demographics at the study site, and their applicability to diverse ethnic groups might be limited. Furthermore, the variances in mastectomy techniques, including variations in skin involvement, could potentially impact both breast weight and volume measurements.

Conclusions

Accurate breast tumor volume measurement is a key factor in achieving symmetry in breast reconstruction. By combining existing data, such as the weight of the resected breast tissue and mammographic density findings, a considerably easy and accurate way to calculate the resected breast volume can be introduced.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://gs.amegroups.com/article/view/10.21037/gs-23-262/rc
Data Sharing Statement: Available at https://gs.amegroups.com/article/view/10.21037/gs-23-262/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-23-262/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional review board of the Faculty of Medicine at Chulalongkorn University in Bangkok, Thailand (IRB number 338/53), and informed consent was obtained from all individual participants.

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