The BREAST-V: A Unifying Predictive Formula for Volume Assessment in Small, Medium, and Large Breasts

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Background: Breast volume assessment enhances preoperative planning of both aesthetic and reconstructive procedures, helping the surgeon in the decision-making process of shaping the breast. Numerous methods of breast size determination are currently reported but are limited by methodologic flaws and variable estimations. The authors aimed to develop a unifying predictive formula for volume assessment in small to large breasts based on anthropomorphic values.

Methods: Ten anthropomorphic breast measurements and direct volumes of 108 mastectomy specimens from 88 women were collected prospectively. The authors performed a multivariate regression to build the optimal model for development of the predictive formula. The final model was then internally validated. A previously published formula was used as a reference.

Results: Mean (±SD) breast weight was 527.9 ± 227.6 g (range, 150 to 1250 g). After model selection, sternal notch–to-nipple, inframammary fold–to-nipple, and inframammary fold–to–fold projection distances emerged as the most important predictors. The resulting formula (the BREAST-V) showed an adjusted R^2 of 0.73. The estimated expected absolute error on new breasts is 89.7 g (95 percent CI, 62.4 to 119.1 g) and the expected relative error is 18.4 percent (95 percent CI, 12.9 to 24.3 percent). Application of reference formula on the sample yielded worse predictions than those derived by the formula, showing an R^2 of 0.55.

Conclusions: The BREAST-V is a reliable tool for predicting small to large breast volumes accurately for use as a complementary device in surgeon evaluation. An app entitled BREAST-V for both iOS and Android devices is currently available for free download in the Apple App Store and Google Play Store. (*Plast. Reconstr. Surg.* 132: 1e, 2013.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Diagnostic, II.

Breast volume assessment is one of the most important steps during the preoperative setting of every breast surgery procedure. Predicting breast volume may be helpful as an indication for reduction mammaplasty and for calculating resection weight preoperatively, which is key information needed for insurance companies and social security compensation.[1] Indeed, many insurance companies do not support breast reduction weight not exceeding 500 g; thus, a correct preoperative weight estimate is required.[2] Moreover, discernment of the postoperative breast size is also functional for the correction of breast asymmetries both for aesthetic and for reconstructive procedures. Even though adequate preoperative evaluation usually depends on experience, skill, and surgical ability, numerous methods of breast size determination have been reported to enhance the clinical evaluation. Among them, use of anthropomorphic measurements is seen to be a reliable, cheap,

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fast, and reproducible method. Nevertheless, the validity of studies aiming to find a formula for predicting breast size by investigating possible relationships between anthropomorphic values and breast volume is debatable because direct breast volumes come from methods that are controversial and open to criticism.[3–7] Therefore, the purpose of our study was to investigate possible relationships between anatomical measurements of the breast and its size using volumetric evaluation of breast specimens from mastectomy, to establish a unifying mathematical formula to be used for small, medium, and large breasts.

Breast Volume Assessment Methods

Qiao et al.[3] proposed a formula presuming the breast to have a cone geometric shape, which could be useful for small breasts, but it does not apply to individual anatomical variability or to larger breasts that typically have a cylindrical shape. Westreich[4] attempted to identify correlations between breast volume and multiple breast and torso parameters, limited by the use of the Grossman-Roudner device (i.e., transparent graduated disks, formed as adjustable cones, in which the breast is placed and the volume is obtained by the calibration marked on the disks). This technique is limited by the same assumption as that of Qiao et al. and by incomplete cone filling with firm or small breasts.[4] Although it has been shown to be accurate in breast volume below 425 cc, it is operator dependent, as breast compliance and pressing force applied generate nonhomogeneous and unreliable values. Sigurdson and Kirkland[6] reported a formula for hypertrophic breasts, collecting volumetric measurements with a modified Tezel water displacement technique. It has been criticized that cylindrical containers have standard diameters not perfectly matching breast edges with the patient lying in supine position. It does not adequately measure the breast tissue squeezing out laterally to the pectoral edge or the breast Spence's tail or the parenchyma above the flat chest wall, spread and distorted by the hydrostatic pressure and subjective manipulation.[4,7] Some authors have confirmed this concern, stating that they consciously omitted collecting data regarding breast circumference, compromised by a lack of clearly defined landmarks.

The only objective method considered as the criterion standard that guarantees correct and consistent values of breast volume consists of measurement of breast specimens from mastectomy.[8] Despite this, no study has attempted thus far to correlate anthropomorphic values to breast volume using breast specimen weight, just as certainly as no one was capable of identifying a reliable formula possibly applicable to predicting the volume of small to large breasts.

PATIENTS AND METHODS

From March of 2008 to April of 2011, 88 women undergoing modified radical mastectomy according to Madden et al.[9] performed by a single surgeon were enrolled prospectively in this study. Demographic data regarding age, height, weight, body mass index, and 10 anthropomorphic measurements were collected preoperatively by a single evaluator (Table 1), whereas direct weight of 108 breasts specimens was determined intraoperatively

Table 1. Descriptive Statistics for Anthropomorphic Measurements and Patient Data

Variable	Mean ± SD	Range	No.
Patient age, yr	51.3 ± 9.13	30–75	88
Patient height, cm	162.7 ± 5.43	150–176	88
Patient weight, kg	65.7 ± 11.78	43–95	88
BMI, kg/m^2	25.35 ± 3.79	17.74–33.87	88
Breast specimen weight, g	527.90 ± 227.60	150–1250	108
Right breast weight, g	545.20 ± 216.46	180–1250	53
Left breast weight, g	491.56 ± 219.23	150–1050	55
SN, cm	24.73 ± 3.48	18–38	108
EN, cm	24.96 ± 3.15	17.5–32.5	108
FN, cm	9.26 ± 3.20	4–19	108
BW, cm	16.65 ± 4.80	5.5–31	108
AW, cm	4.79 ± 1.10	2.5–8	108
LL_O, cm	46.24 ± 4.24	39–56	108
LL_S, cm	47.94 ± 5.53	39–61	108
MM, cm	34.86 ± 6.45	23–58	108
FF_P, cm	14.53 ± 4.28	7–25	108
EQ, cm	29.26 ± 4.53	16–40	108

BMI, body mass index; SN, sternal notch–to-nipple distance; EN, midclavicular-to-nipple distance; FN, fold-to-nipple distance; BW, breast width; AW, areolar width; LL_O, breast base circumference in orthostatism; LL_S, breast base circumference in supine position; MM, breast circumference at the level of the inframammary fold; FF_P, fold-to-fold projection point distance; EQ, breast equator.

Table 2. Multivariate Polynomial Regression Model

Variable	RC (B)	SE	*t* Statistic	*p*
Sternal notch–to-nipple^2	0.5747	0.0772	7.444	3.20e-11
Fold-to-fold projection	18.5478	3.4098	5.440	3.68e-07
Fold-to-nipple	14.5087	3.6785	3.944	0.000147
Intercept	–231.6644	47.5031	–4.877	3.98e-06

RC, regression coefficient.

using a scale, excluding possible axillary tissue connected to mastectomy specimens. The ethical committee of Sant'Andrea Hospital, School of Medicine and Psychology, "Sapienza" University of Rome approved the study protocol. Patients were asked whether they were willing to participate to our study, and written informed consent was obtained from all of the accepting subjects.

Statistical Analysis

A polynomial regression (i.e., linear regression also with squares and cubes of the predictors) was performed to build the optimal model for the development of the BREAST-V (i.e., breast volume assessment), a mathematical predictive formula for breast volume assessment. All available predictors and their square and cubic transformations were considered for inclusion in a multivariate regression model, where breast weight was the outcome. We have compared our model with the results from a mixed regression that is more appropriate, as dependence arising from breasts measured on the same woman would then be taken into account, but decided to report a fixed effects model because the results were similar and the latter model is less complex.

We then selected a subset of the model that included all possible predictors, their squares, and their cubes by minimizing the Akaike information criterion,[10] which is tailored to optimize the predictive performance. The final model was then internally validated through cross-validation: we randomly split the data so that we fit the model based on approximately 75 percent of the breasts and then predicted the outcome of the remaining 25 percent. We use this strategy to assess the performance of the model on new breasts, not used for estimation. We repeated this "randomly split and estimate" operation 1000 times and therefore were able to estimate the average absolute and relative errors. These are defined as the absolute difference between predicted and observed weight, and the latter is divided by the observed weight. Given that the error is assessed on breasts that are not used to fit the model, the values we report can be deemed to be the expected errors when our predictive formula is used in the clinical setting, provided that breasts arise from the same population (i.e., with the same weight range).

As a comparison, we used the predictive formula of Sigurdson and Kirkland,[6] applying their predictive model to the volume range suggested by the authors (i.e., 500 to 2400 cc). We adopt a 1:1 conversion of volume to weight[10] for this comparison; no meaningful differences are seen with other conversion factors anyway.[11]

All data were expressed as mean ± SD, and a value of $p < 0.05$ was considered as statistically significant. All analyses were performed using R software (version 2.14.2).[12]

RESULTS

The mean ± SD breast weight was 527.9 ± 227.6 g. The minimum weight was 150 g, and the largest was 1250 g. After model selection, the final predictive model is shown in Table 2 and consequently our final predictive formula is as follows:

$$\begin{aligned}\text{BREAST–V} = {} & -231.66 + 0.5747 \times (SN)^2 \\ & + 18.5478 \times (FF_p) \\ & + 14.5087 \times (FN)\end{aligned} \quad (1)$$

where SN is the sternal notch–to-nipple distance, FF_p is the fold-to-fold projection point distance, and FN is the fold-to-nipple distance.

The R^2 of the model is 0.73 (adjusted R^2, 0.72), meaning that approximately three-fourths of the information about breast volume is contained in the three predictors. To emphasize that the predictive ability of our formula fits well, we report in Figure 1 the observed and predicted weights.

To assess the predictive performance of the BREAST-V, we report the results of cross-validation. The expected absolute error on new breasts is estimated as 89.7 g (95 percent CI, 62.4 to 119.1 g) and the expected relative error is 18.4 percent (95 percent CI, 12.9 to 24.3 percent).

Application of the Sirgudson and Kirkland formula on our sample did yield worse predictions

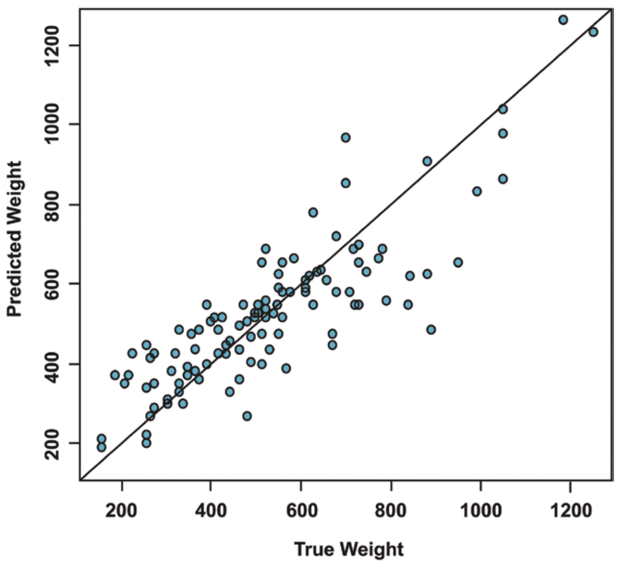

Fig. 1. Predicted and true weights of mastectomy specimens.

than those predicted by our formula, which relies on only one additional factor. We do believe that the superior performance of our approach resides in the use of the square of the sternal notch–to-nipple distance, which is the most important predictor of our data.

The Sigurdson and Kirkland formula yields an overall R^2 of 0.55, which is well below our $R4^2$ of 0.73. With cross-validation, we could obtain a 95 percent confidence interval for the R^2 of their formula (i.e., 0.50 to 0.64). Therefore, we can safely assess that the BREAST-V has a *significantly* better R^2 than the formula of Sirgudson and Kirkland, given that 0.73 is outside the confidence interval. The absolute error with the formula of Sigurdson and Kirkland on our data is 181.4 g, and the relative error is 25.1 percent. Both figures are clearly above the upper bounds of our confidence intervals for the prediction error of the BREAST-V. Even if we use a conversion factor of 1.06 for the predicted weight[13] as a function of the predicted volume, we get exactly the same results in terms of R^2 and relative error, whereas the absolute error is 138.4 g.

DISCUSSION

Different authors have previously investigated relations between anthropomorphic values and breast volume, but variable results emerging from these studies have led to different predictive formulas according to breast size.[3,4,6,14–17] This variability was probably attributable to heterogeneity of breast volume measurement techniques that alternatively conformed to different sized breasts. The Grossman-Roudner device is seen to be reliable and is preferentially used for small breasts,[5] and the water displacement technique has been more frequently applied to medium to large breasts.[6] Despite their applications, few studies have objectively investigated the reliability of these methods by comparing their results with breast volume measurements from mastectomy specimens.[18,19] Therefore, until now, the most accurate method with which breast volume can be directly derived remains specimen volume. In our study, we enrolled only women scheduled for modified radical mastectomy with excision of the overall skin and subcutaneous breast tissue performed by a single surgeon, thus excluding breast specimens from more conservative approaches such as skin-sparing or nipple-sparing mastectomy to eliminate residual breast volume variability. Furthermore, to make homogeneous material, a single evaluator collected data on anthropomorphic measurements and breast specimen weights from all of the participants of the study.

Among all anthropometric variables included in our model, the sternal notch–to-nipple distance is seen to be the most important predictor of breast volume. In contrast to some authors,[6] this result compares with other studies[4,17] confuting the hypothesis that this anatomical distance is prone to be inaccurate because of its dependence on different factors such as thoracic length and patient height. In our sample, the variability of breast base position on the chest wall also emerged not to significantly bias this predictor. The other two significant predictors were fold-to-fold projection point distance and fold-to-nipple distance. It seems quite obvious that the greater the size of the lower pole, the greater the breast volume. Therefore, as breast volume increases, the fold-to-fold projection point distance and fold-to-nipple distance must become larger as well. In contrast, measurements of breast circumference in both supine and erect positions were found irrespective of breast volume, as they emerged not significantly related. As a consequence, it can be supposed that indefinite landmarks of these distances cause more variable results.

To further verify the goodness of fit of our model, we compared the BREAST-V with a formula proposed by Sirgudson and Kirkland,[6] who conducted a study of anthropometric values from breasts with a range similar to that of our subjects; thus, this seemed to be an appropriate study with which to perform a comparison. As a result, the BREAST-V emerged as more accurate and reliable for predicting breast volumes than the formula

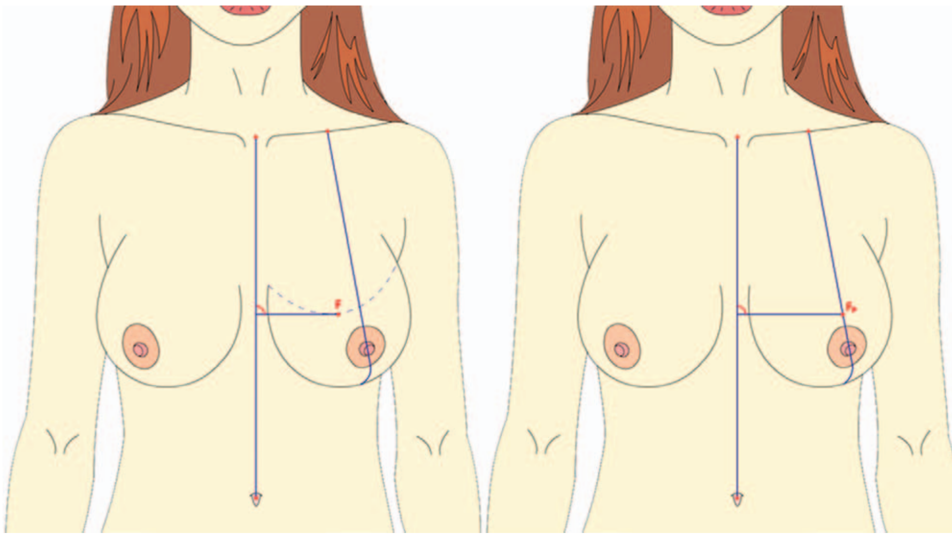

Fig. 2. Diagram showing the two-step method of localizing the inframammary fold projection to the anterior surface of the breast meridian point. (*Left*) First, with the patient in standing position and the arms left at the patient's sides, standard marking such as chest midline from the sternal notch to umbilicus, inframammary fold, and breast meridian from the clavicle down through the mound is performed. (*Right*) Next, a horizontal line is marked from the most caudal point of the inframammary fold (F) to the chest midline and subsequently extended to the anterior surface of the breast. The intersection of this horizontal line with the breast meridian identifies the inframammary fold projection to the anterior surface of the breast meridian (F_p) point.

suggested by Sirgudson and Kirkland. This could be explained by the inherent limitations of the water displacement technique as a method for breast volume measurement used by Sirgudson and Kirkland, as this procedure tends to predict smaller breast volumes than those expected. Furthermore, the two predictors of their formula are based on the "finger test," which is a quite approximate approach for identification of the inframammary fold projection point to the anterior surface of the breast. Indeed, differences in its location resulting from thick breast bases or operator-dependent variable approaches could lead to nonhomogeneous and unpredictable results.[6] In our study, we identify this anatomical landmark through two steps. First, standard breast marking including chest midline from the sternal notch to the umbilicus, inframammary fold, and breast meridian from the clavicle down through the mound are drawn with the patient in standing position and the arms left at the patient's sides. Next, a horizontal line is marked from the most caudal point of the inframammary fold to the chest midline and subsequently extended to the anterior surface of the breast. The intersection of this horizontal line with the breast meridian identifies the inframammary fold projection to the anterior surface of the breast meridian point (Fig. 2). As a consequence, our four well-defined anatomical landmarks (i.e., sternal notch at the center of the jugular fossa, center of the nipple, most caudal midpoint of the inframammary fold, and inframammary fold projection to the anterior surface of the breast meridian) make the

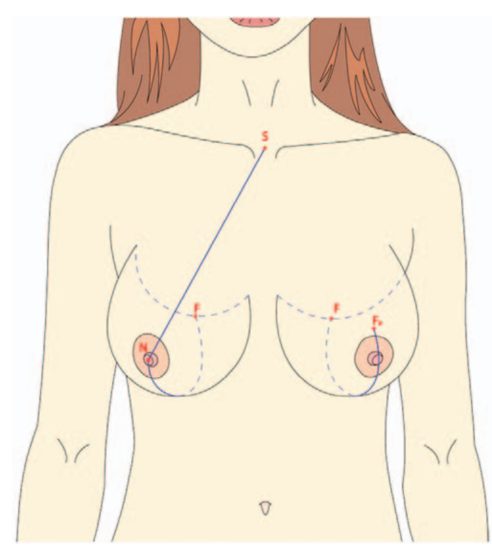

Fig. 3. Anatomical distances included in the BREAST-V formula. *S-N*, sternal notch–to-nipple distance; *F-N*, fold-to-nipple distance; F-F_p, fold-to-fold projection distance; *S*, sternal notch at the center of the jugular fossa; *N*, center of the nipple; *F*, most caudal midpoint of the inframammary fold; F_p, inframammary fold projection to the anterior surface of the breast meridian.

BREAST-V a method that is more reproducible and easier to apply (Fig. 3). Moreover, from a statistical point of view, we performed a *polynomial* regression, thus also including squares and cubes of the predictors given that some relationships are inherently nonlinear. The breast volume, which is a proxy of our target outcome, may be a better predictor, for instance, with the square of the base among other factors than with the base itself, as the square of the base is involved in the volume of a cone, truncated cone, and cylinder. Any predictive formula not taking into account nonlinear relationships could be improved by inclusion of squares and cubes of predictors.

However, the BREAST-V has the limitation of being appropriately applied to pseudoptotic and ptotic breasts according to the Regnault classification,[20] as one of the predictors included in the formula (i.e, fold-to-fold projection point distance) is based on the anterior projection of the inframammary fold, measurable only in sagging breasts. Thus far, it can be fittingly applied to women with breast sizes ranging from 150 to 1250 cc, and future investigations will be required to further validate the formula on breast volumes out of our range. In spite of this, the BREAST-V is the first unifying predictive formula for volume assessment in small to large breasts representing a valid and reliable tool that can be appropriately applied in the preoperative setting of every breast surgery procedure. Clinically, the use of the BREAST-V in mammaplasty procedures may be useful for preoperative assessment to determine and quantify the presence of asymmetry. Even if the formula has an absolute error of approximately 90 g, it has to be specified that by applying the formula to each breast, it will yield different volumes because the weight distribution is symmetric after accounting for covariates, and no asymmetry in prediction will be expected. Therefore, this information can be used to adjust volume differences either using different quantities of fat grafting, different sized implants, or different breast volumes to be removed. Similarly, with the goal of reconstructive breast surgery for unilateral reconstruction being to gain symmetry with the contralateral breast, it follows that the instrument will be helpful for predicting the volume of the latter one. The BREAST-V may also be functional for patients undergoing bilateral mastectomy who wish to have reconstructed breasts similar to their current size. The formula can be easily applied using a simple calculator or mobile phone; to enhance its application, we released an app entitled BREAST-V for both iOS devices such as iPod, iPhone, and iPad (all versions) and Android smartphones currently available to be downloaded for free on Apple's online App Store and Google Play Store. Notwithstanding its accuracy, it has to be kept in mind that the BREAST-V must not be considered as an alternative but as a complementary device to be combined with the experience, aptitude, and ability of the surgeon approaching the decisional process of every breast-shaping procedure.

CONCLUSIONS

The BREAST-V can provide reliable, predictable, and reproducible data regarding breast volume in small, medium, and large breasts. This new device may help surgeons to provide important data to enhance their clinical and surgical performance of both aesthetic and reconstructive breast procedures.

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