Original Article

Validation of plastic cups, water displacement and breast density and weight as methods for measurement of breast volume

Wahida Chakari[1]^, Navid Toyserkani[2]^, Rikke Bredgaard[3], Tove Filtenborg Tvedskov[4]^

[1]Department of Plastic and Breast Surgery, Odense University Hospital, Odense, Denmark; [2]Department of Plastic Surgery and Breast Surgery, Zealand University Hospital, Roskilde, Denmark; [3]Department of Plastic Surgery, Herlev Hospital, Copenhagen, Denmark; [4]Department of Breast Surgery, Gentofte Hospital, Copenhagen, Denmark

Contributions: (I) Conception and design: All authors; (II) Administrative support: W Chakari, TF Tvedskov; (III) Provision of study materials or patients: W Chakari, TF Tvedskov, R Bredgaard; (IV) Collection and assembly of data: W Chakari, TF Tvedskov, R Bredgaard; (V) Data analysis and interpretation: W Chakari, N Toyserkani, TF Tvedskov; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Wahida Chakari, MD. Department of Plastic and Breast Surgery, Odense University Hospital, J. B. Winsløws Vej 4, 5000 Odense, Denmark. Email: wahida.c@hotmail.com.

Background: Accurate breast volume measurement is essential for breast and plastic surgeons in surgery planning. Though the use of plastic cups is an inexpensive and non-invasive method for measuring breast volume, its validation has been infrequent. The aim of this study was to investigate the reliability of breast volume measurements using plastic cups.

Methods: From January 2019 to May 2019, we conducted preoperative breast volume measurements on all female patients undergoing skin- or nipple-sparing mastectomy and primary reconstruction with breast implants at Rigshospitalet, Copenhagen, Denmark. Plastic cups were used for these measurements. During surgery, the mastectomy specimen's weight was measured, and its volume was estimated through fluid displacement. Breast density data were obtained from preoperative mammography reports, and volume was subsequently calculated using density and weight.

Results: Seventeen breasts were analyzed. There was poor agreement between the volume measured with plastic cups and the volume estimated through water displacement, with a correlation coefficient of only 0.73 ($P<0.01$). The mean difference in measured volume between the two methods was –12 mL, suggesting that the plastic cups tended to overestimate the volume. Likewise, there was a poor agreement between the volumes measured with plastic cups and those calculated from weight and density, with a correlation coefficient of 0.87.

Conclusions: Our study revealed a significant discrepancy between breast volumes measured by plastic cups and those determined by water displacement techniques or calculated by breast density and weight. In general, the plastic cups method overestimated breast volume. However, plastic cups remain an inexpensive and non-invasive means for breast volume measurement and may still serve as a valuable tool when taking this volume overestimation into account.

Keywords: Plastic surgery; breast surgery; breast volume; volume measurement; plastic cups

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^ ORCID: Wahida Chakari, 0009-0000-7337-5485; Navid Toyserkani, 0000-0001-5619-4711; Tove Filtenborg Tvedskov, 0000-0002-7568-1790.

Introduction

A correct measurement of the breast volume is helpful information for the breast and plastic surgeon. Breast volume measurements can be helpful in planning a variety of breast operations, including those for macromastia and asymmetry. Knowledge of breast volume helps the surgeon in selecting the right implant size for breast reconstruction or augmentation and in achieving breast symmetry in oncoplastic surgery. In breast reduction mammoplasty, the volume measurement can be used to identify patients suitable for the procedure (1-3). Today, measurement of breast volume is a well-integrated and essential clinical tool in reconstructive breast surgery.

Over the years, several methods have been used to assess breast volume. Imaging technology such as magnetic resonance imaging (MRI) (4,5), ultrasound, computed tomography (CT), three-dimensional (3D) imaging (2) and mammography (6) have been used, but other methods like biostereometric techniques such as Grossman-Roudner cone and anthropomorphic measurements which is based on calculating distance between a set of anatomical landmarks, casting techniques, and water displacement (Archimedes' principle) (5-7) have also been used to evaluate breast volume. Latest, methods using advanced software have been introduced such as 3D scanners and web-based algorithms (8-10). However, few of the mentioned methods have been validated in scientific studies, where specimen volume has been used as controls (11) and none of the techniques have been "commonly accepted" for everyday clinical use. Some of the methods that claim accuracy in measuring breast volume are expensive, time-consuming and difficult to establish in standard practice due to lack of sufficient access to special software or scanners (5). A measurement for clinical everyday use should be cheap, fast, user friendly, non-invasive, and most importantly radiation-free. A method that possesses all these qualities is measuring of breast volume using plastic cups first described in 1986 by Strömbeck and Malm (12). A set of round plastic cups with a standard interval of 50 mL is used to evaluate the breast volume. The method is being used for measurement of breast volume in plastic surgery and breast surgery clinics around the world. However, like other methods, measuring breast volume with plastic cups have only been sparsely validated in smaller patient series without standardized use of control (12,13). The aim of this study was to investigate the reliability of breast volume measurements using plastic cups.

Highlight box

Key findings

- Plastic cups offer a cost-effective, non-invasive method for preoperative breast volume measurement.

What is known and what is new?

- Plastic cups have been evaluated in two studies for breast volume measurement. Their accuracy can differ depending on the user. Notably, one study found them to be more accurate than magnetic resonance imaging and three-dimensional scanners.
- Our research indicates that plastic cups may overestimate breast volume by 12 mL. Nevertheless, this overestimation is smaller than with other measurement tools.
- Specimen weight and mammogram density are less accurate than water displacement for estimating breast volume.

What is the implication, and what should change now?

- Plastic cups can be used to measure breast volume preoperatively however they may overestimate the breast volume. Their simplicity, affordability and non-invasive nature, make them a valuable tool for breast volume measurements.

Methods

Between January 2019 and May 2019, female patients undergoing skin-sparing or nipple sparing mastectomy and primary reconstruction with breast implants at the department of breast surgery at Rigshospitalet, Copenhagen, Denmark were consecutively included in the study. No patients had thoracic deformities. All patients had a preoperative mammography less than 6 months before surgery. Height and weight of the patient were measured few days preoperatively, and body mass index (BMI) was calculated. Preoperatively, the breast volume was evaluated objectively by a senior consultant plastic surgeon using plastic cups. The evaluation was divided between two different consultants. At surgery, the weight of the fresh, non-fixated mastectomy specimen was measured using a digital weight and the volume was measured by fluid displacement (Archimedes' principle). Volume estimated by fluid displacement was considered the true volume of the breast. The volume estimated using plastic cups was combined with additional details, such as the width and height of the patient's breast footprint, to guide the selection of the implant.

Measuring of breast volume with plastic cups (cup-volume)

The breast volume cups utilized are the same as those described by Strömbeck and Malm. These come in a

standard set, manufactured by the Swedish company Emballageform AB (12). The round cups were used to measure breast volume with the patient in an upright sitting or standing position and with her arms hanging down. Eleven different cup sizes were used: 200, 275, 350, 500, 650, 850, 950, 1,150, 1,350, 1,600 and 2,000 cc. The volume was measured by lifting the breast with one hand and putting the rim of the cup in the inframammary fold and in this way letting the breast fall into the cup. Thereafter the cup was pushed firmly against the thoracic wall and the volume was evaluated. If the cup did not get filled completely a smaller cup was used. If breast tissue remained outside of the rim, a larger cup was used. If the measured volume fell between two cup sizes, a best estimate was made by the surgeon. Below 750 cc, this estimate was made at 25 cc intervals, i.e., 475 cc; above 750 cc the interval used was 50 cc.

Measurement of breast volume by water displacement (mastectomy volume)

The fluid displacement was carried out in a vessel filled with water. The mastectomy specimen was placed in a plastic bag, all the air was squeezed out and the bag was sealed. Thereafter the specimen in the plastic bag was placed in the vessel with water. The volume of water displaced by the specimen was measured.

Measurement of breast volume by using weight

The weight of the specimen was used to calculate the volumes by using the equation breast volume = breast mass/ρ, in alignment with the methodology outlined in the study conducted by Rostas *et al.* (14). Information on individual breast density was collected from the preoperative mammography report where breast density was scored according to the Breast Imaging Report and Data System (BIRADS) mammographic density categories 1 to 4. Quantitative density values are assigned to mammographic categories (14):

(I) <10% glandular tissue, ρ =0.916 g/mL
(II) 11–50% glandular tissue, ρ =0.944 g/mL
(III) 51–75% glandular tissue, ρ =0.972 g/mL
(IV) >75% glandular tissue, ρ =1.0 g/mL

Statistical analysis was performed with SPSS (IBM Corp., released 2020, IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY, USA).

Continuous data was presented with mean ± standard deviation (SD) or median (range) depending on distribution pattern. The agreement between the between measurement techniques was assessed by Bland-Altman plot and Lin's Coefficient of Concordance, and the correlation coefficient was calculated. Strength of agreements were evaluated according to the criteria by McBride (15).

Graphs were made in GraphPad Prism (GraphPad Prism version 6.0.0 for Windows, GraphPad Software, San Diego, CA, USA; https://www.graphpad.com/).

Ethical consideration

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013), and approved by the Hospital Administration (Rigshospitalet, Copenhagen) as a quality control project (No. 18015437). Patients were offered standard treatment therefore additional permission and informed consent were not required.

Results

Thirteen women undergoing mastectomy and primary breast reconstruction with an implant were included in the study. Ten patients had skin-sparing mastectomy while only three patients had nipple-sparing mastectomy. Both patients with bilateral and unilateral mastectomies were included, which resulted in 17 breasts available for analysis. In total nine patients underwent unilateral mastectomy, and four patients underwent bilateral mastectomy. Ten patients had surgery due to invasive carcinoma and three patients due to ductal cancer *in situ*. In all four patients with bilateral mastectomy the contralateral mastectomy was prophylactic. Mean age at surgery was 47 years, and mean BMI was 23 kg/m^2 (*Table 1*). *Table 1* shows breast volume measurements obtained using plastic cups (cup volume), water displacement technique (mastectomy volume), and weight and density (weight/density volume). The mean cup volume was 366 mL, the mean mastectomy volume was 354 mL, and the weight/density volume was 308 mL.

A poor agreement was found between volumes measured by plastic cups *vs.* volume obtained through water displacement technique, with a Lin's Coefficient of Concordance on ρ_c =0.723 and a correlation coefficient of only 0.73 (P<0.01) (*Figure 1*). The mean difference in measured volume between the two methods was –12 mL [95% confidence interval (CI): –212 to 188 mL], which

Table 1 Patient characteristics and breast volume in 13 patients undergoing mastectomy and reconstruction

Variables	No. of patients/breasts	Mean	Std. deviation	Min.	Max.
Age (years)	13	47	–	30	79
Height (cm)	13	168	–	150	182
Weight (kg)	13	66	–	50	87
Mastectomy weight (g)	17	302	126	138	575
Cup volume (mL)	17	366	129	200	650
Mastectomy volume (mL)	17	354	141	120	650
Weight/density volume (mL)	17	308	130	138	592

Std., standard; Min., minimum; Max., maximum.

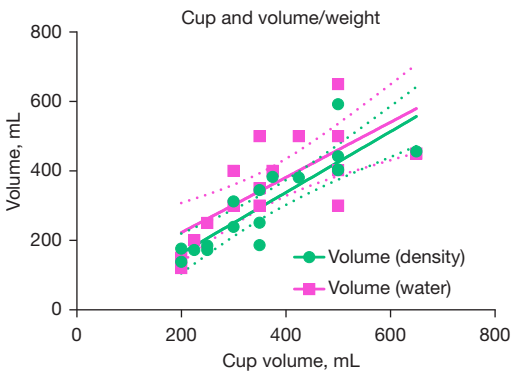

Figure 1 Correlation between volume estimated by cups *vs.* estimated by water displacement or volume calculated by breast density and weight.

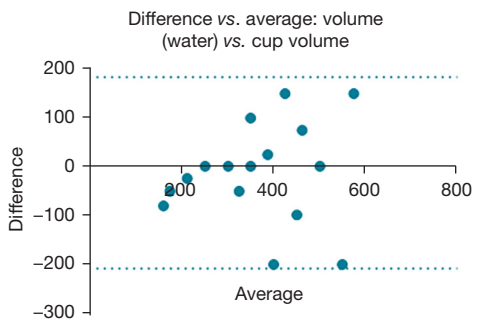

Figure 2 Bland-Altman plot of agreement between cup volume and volume estimated by water displacement.

indicates that the plastic cups overestimate the volume with 12 mL compared to water displacement (*Figure 2*). However, a great variety in volume difference was seen from underestimation on 150 mL and up to 200 mL overestimation of the breast volume obtained by plastic

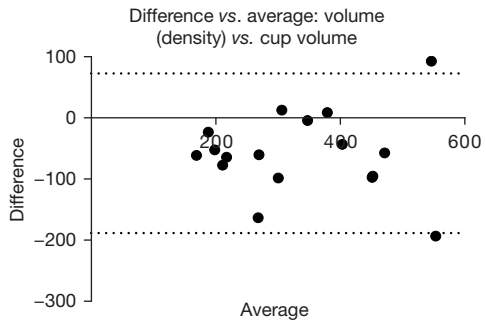

Figure 3 Bland-Altman plot of agreement between volume estimated by plastic cups and volume calculated by weight and density.

cups compared to water displacement technique.

Likewise, a poor agreement was found between volumes measured by plastic cups *vs.* volume calculated from weight and density, with a Lin's Coefficient of Concordance on ρ_c =0.79 and a correlation coefficient on 0.87 (P<0.01) (*Figure 1*). The mean difference in measured volume between the two methods was 58 mL (95% CI: −72 to 189 mL), indicating that the plastic cups overestimated the volume with 58 mL compared to volume calculated by weight and density (*Figure 3*). Again, a great variety in volume difference was seen from underestimation of 92 mL and up to 194 mL overestimation of the breast volume obtained by plastic cups compared to weight and density.

A better but still poor agreement was found when comparing volume calculated from weight and density to water displacement volume, with a Lin's Coefficient of Concordance on ρ_c =0.826 and a correlation coefficient of 0.88 (P<0.01). The mean difference in volume was 46 mL (95% CI: −91 to 183 mL), which indicates that the density volume underestimates the volume with 46 mL compared to

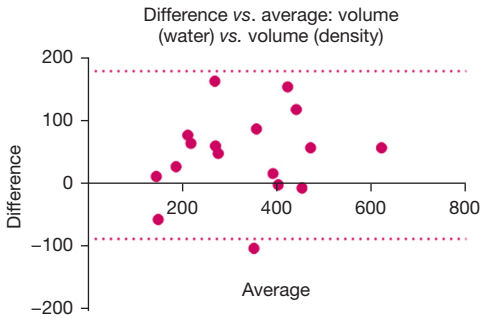

Figure 4 Bland-Altman plot of agreement between volume calculated by breast density and weight and volume estimated by water displacement.

volume estimated by water displacement (*Figure 4*). Again, a great variety was seen in the calculated difference was seen from underestimation on 155 mL and up to 104 mL overestimation of the breast volume obtained by calculation from weight and density compared to water displacement.

Discussion

In this study we have investigated the validity of plastic cups for preoperative measurement of breast volume. We found a very poor agreement between volume measured by plastic cups and volume of the breast specimen at surgery either by using weight and density or water displacement. In general, the plastic cups overestimated the breast volume, while volume calculated by weight and density tended to underestimate volume compared to water displacement. Only two other studies have evaluated plastic cups for measurement of breast volume. One study carried out by Hansson *et al.* investigated reliability of the plastic cups by letting 13 different raters estimate the breast volume using plastic cups (13). The study showed that the volume was either overestimated or underestimated with a mean of 56 mL. The other study carried out by Eriksen *et al.* compared four different techniques to estimate breast shape and volume, the techniques included were MRI, plastic casts, plastic cups, and 3D scanner (11). Like in our study the breast volume obtained by water displacement (Archimedes) served as control. The study showed that MRI and 3D scanners overestimated the volume while the plastic cups were the most accurate technique for estimation of the breast volume but gave poor or no information about the breast shape. The study did however only include six breasts. A systematic review by Choppin *et al.* included 15 studies where seven different breast volume measurement techniques were compared but plastic cups were not used in any of the studies (6). In all the studies volume obtained by water displacement or mastectomy weight was used as a control (golden standard). The systematic review concluded that all the available techniques either overestimates or underestimates the volume with a mean of 200 mL.

The overestimation of breast volume by plastic cup measurement found in our study can be explained by several factors. First, cup measurement is dependent on the surgeon's technique for using the cups. One previous study did show low agreement between surgeons when using plastic cups with a variation between different rates on 14%. In our study, only two surgeons participated in evaluation of plastic cup volume, however there could still be a difference in their estimation. In some cases, all the breast tissue might not have been inside the cup, or it could have been too much air inside the plastic cup, in both cases the rater should have either chosen a smaller or a bigger plastic cup. Furthermore, the plastic cups estimate a volume that include: epidermis, dermis, nipple and areola complex and breast tissue, while the volume obtained by water displacement is only based on the breast tissue and in some cases also the nipple and areola complex. This could explain the overestimation of breast volume by the plastic cups, especially in the cases where the nipple and areola complex are sparred. In addition, the interval between cup size leaves a certain volume for the surgeons judgement for choosing the cup with the best fit. Finally, a sample size on only 17 breasts could result in variations caused by chance. The sample size did not allow stratification according to breast size. A study of a larger scale is needed to allow for stratification and to substantiate the results. Our results of density and weight underestimating breast volume compared to volume estimated by water displacement indicates that weight of the specimen in combination with density from mammograms is not very precise in estimating breast volume. When testing new methods for volume estimation, water displacement should be preferred.

Conclusions

Information about the breast volume is important in many clinical scenarios for breast and plastic surgeon. None of the existing techniques are an ideal method for breast volume measurements in every day clinical situations. Despite the weaknesses described in measurement of breast volume by plastic cups, the mean difference in volume

found in our study on only 12 mL is lower than what found by other techniques (6). The plastic cups for breast volume measurement is a cheap and non-invasive method and might still be used as a valuable tool for evaluating the breast volume preoperatively.

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Footnote

Data Sharing Statement: Available at https://abs.amegroups.com/article/view/10.21037/abs-23-62/dss

Peer Review File: Available at https://abs.amegroups.com/article/view/10.21037/abs-23-62/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://abs.amegroups.com/article/view/10.21037/abs-23-62/coif). T.F.T. is Head of the Danish Breast Cancer Group surgical board who describes national guidelines for treatment of breast cancer, including breast reconstruction. The other 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), and approved by the Hospital Administration (Rigshospitalet, Copenhagen) as a quality control project (No. 18015437). Patients were offered standard treatment therefore additional permission and informed consent were not required.

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