

The Cost Effectiveness of Three Different Measures of Breast Volume

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Abstract

Background: Several methods including water displacement, casting, the Grossman–Roudner measuring device, photographs, mammograms, ultrasound, and magnetic resonance imaging (MRI) have been proposed for the measurement of breast volume. The most cost-effective method has not been determined.

Methods: This study compared breast volume measurements using the Grossman–Roudner measuring device (a piece of circular plastic with a cut along a radius line), plaster casting, and MRI. The Grossman–Roudner measuring device was formed into a cone around the breast, and the volume was read from a graduated scale on the overlapping edges. The volume of the cast was measured using a butter–sand mixture and water displacement. The volume from the MRI slices was calculated using the ANALYZE bioimaging software. For five women with breast sizes AA, A, B, C, and D, the three volume measures were repeated three times. For a single volume measurement, the cost of the time and materials was \$1 for the Grossman–Roudner cone, \$20 for the cast, and \$1,400 for the MRI. Using the mean and standard deviations of the measurements, a power analysis determined the number of subjects needed to detect a 5% change in volume. The number of subjects was multiplied by the price per test to determine relative cost.

Results: As compared with the cost for the Grossman–Roudner cone method, the cost for the volume measurements was 64 to 189 times more using the cast and 373 to 33,500 more using MRI.

Conclusion: The Grossman–Roudner cone was clearly the most cost-effective method for determining breast volume

changes in studies testing topical therapies to alter breast size.

Key words: Breast—Cast—Cost—Grossman—Roudner—MRI—Volume

Our clinical research program is preparing to test the use of topically applied compounds to increase breast size as a medical substitute for surgical breast augmentation surgery. To evaluate the efficacy of breast augmentation creams, a validated and reproducible method of measuring breast size is needed. Because women with small breasts most frequently request breast augmentation, any measuring procedure must be capable of measuring very small breast sizes. Previously used breast-measuring systems have focused on breast sizes near the mean, and the applicability of these measurement systems for small breasts is not known.

Breast sizing for bra fitting has used the difference between the chest circumference measured at the rib cage near the submammary crease and the circumference at the nipple level. Although the precision of this measure may be adequate as a starting point for fitting bras in a women's underwear shop, it is too imprecise for use as a scientific outcome measure of breast size, especially when the breasts are ptotic [6].

The Grossman–Roudner breast-measuring device is a circle of flexible plastic with a cut to the center along a radius line. This circle, which can be formed into a cone-shaped device, comes in three diameters appropriate for measuring breasts with volumes of 125 to 200 ml, 200 to 300 ml, and 300 to 425 ml, which roughly correspond to A, B, and C size breasts. The circle is overlapped upon itself to make a cone, and the cone is shaped around the breast, with the volume of the cone determined at the overlap of the

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cut radius on the surface of the cone. The Grossman–Roudner breast-measuring device was formerly available from Cox–Uphoff International (Santa Barbara, CA, USA).

The casting method involves gentle pressure exerted on the breast tissue. The edges of the glandular tissue can be defined, and the edges of the breast tissue can be marked by applying kite string to the chest wall with glue. Making a cast of the breast tissue and measuring the volume of the cast may be a more accurate method of measuring breast size than use of the Grossman–Roudner cone because breasts are not truly conical in shape.

Of the possible methods, MRI gives the greatest anatomic detail, and similar imaging techniques have been used to measure anatomic volumes such as intraabdominal fat [1]. For individuals with cervical cancer, MRI has been used to predict survival by measurement of the tumor volume [7]. Therefore, we thought that measuring breast volume using calculations from an MRI scan would be the most accurate and reproducible method, although the most costly.

This study proposed to compare the volume of the breast measured with the Grossman–Roudner breast-measuring device, the volume measured with a breast cast, and the volume measured from an MRI scan. These methods were compared to determine the reproducibility of the measures over a range of breast sizes. The variability measure was used to determine the number of subjects needed to detect a given difference in breast volume. The number of subjects multiplied by the cost of the test was used to determine the relative cost effectiveness of the three methods.

Methods

Five women who had undergone no breast surgery were included in the study. The women individually represented a bra cup size of AA, A, B, C, or D. Each woman had three separate breast volume measurements using the following three methods.

**Grossman–Roudner breast-measuring device* [3]: This circular plastic measuring device was wrapped around the breast to form a cone, and the volume was read off the overlap of the radius with the surface of the cone while the woman was sitting and leaning backward at a 45° angle. A larger cone was constructed for volumes of 450 to 600 ml, corresponding to size D, adding to the standard sizes A, B, and C that came with the set sold commercially in the past.

**Breast casting*: The women lay in a semirecumbant position, and gentle pressure was applied to the

breast to define the margins of the glandular tissue. Rubber cement (like the glue used to make scrapbooks) was painted at the margins of the glandular tissue for attachment of kite string to the skin to mark the breast tissue margins. Plaster of Paris–impregnated gauze strips (like those used to make splints) were cut to the size of the anterior thorax, dipped in warm water, and applied over the breast, completely covering both the glandular tissue and the string. Three plaster of Paris–impregnated gauze layers were applied and allowed to harden. Then the cast of the breast along with the string was lifted from the chest. Next, the string was removed, leaving a groove in the Plaster of Paris defining the limits of the breast on the inner aspects of the cast. After further drying, the inner portion of the cast was sealed with rubber cement. A 50:50 mixture of fine sand and butter then was placed in the cast and smoothed to the concavity of the chest wall. The volume of the sand–butter mixture was measured by water displacement in a graduated cylinder.

**MRI*: The women underwent an MRI examination of their breasts. The MRI machine, made by Siemens (Munich, FRG), has a 1.5-tesla magnet. The volume of the breast tissue was determined from the MRI data files in the imaging laboratory using a procedure for quantifying visceral fat adapted to the quantification of breast volume. An attempt was made to include only the glandular tissue of the breast in each measure. The volume of each slice of the breast was determined. The total breast volume was calculated by adding the volumes of the individual slices together. The MRI slices were 8.4 mm apart in the sagittal plane, and volume was calculated using the ANALYZE bioimaging software.

Statistical Analysis

The mean and standard deviation for the three breast volume measures from the three methods applied to each subject were used to construct a power analysis that determined the number of subjects needed to detect a 5% change in breast volume with 80% power and an alpha of 0.05. The number of subjects was multiplied by the cost of the test to determine the most cost-effective method.

Results

Three measurements were made for each of the five subjects, using each of the three measurement

Table 1. Measurements of cup sizes AA, A, B, C, and D

	AA (ml)	A (ml)	B (ml)	C (ml)	D (ml)
Cone	160	170	290	325	470
Cone	165	165	300	350	495
Cone	160	180	280	350	515
Cast	251	260	435	475	780
Cast	255	270	430	555	690
Cast	235	320	365	530	655
MRI	347.5	465	512	544	940.2
MRI	377.3	465	475	556	969
MRI	440.7	472	484	524	968

MRI, magnetic resonance imaging.

methods (Table 1). The mean and standard deviation of the mean was calculated for each subject using each of the three measurement methods. A power analysis then was performed to determine the number of subjects needed to detect a 5% change in volume given these variances with 80% power and an alpha of 0.05. The number of subjects needed to detect a 5% change in each subject for each test was multiplied by the cost of the test in question. These costs to detect a 5% change in volume for each of the tests were compared over the range of breast sizes (Table 2).

Measurement of the breast using the Grossman–Roudner cone requires about 10 min for a person paid the minimum wage. Therefore, the volumes measured with this device cost about \$1.00 per measurement.

The casting material is made of gauze impregnated with plaster of paris. This measurement requires about 1 h, with an additional 1 h needed to measure the volume of the breast. For a person paid the minimum wage, this totals about \$12.00. The cost of the material used for each measurement including the gauze impregnated with plaster of paris, kite string, butter, sand, and rubber cement is about \$8.00. Therefore, measurements with this device cost about \$20 per measurement.

Capture of an MRI breast scan requires about 30 min. The total cost for the MRI scan is about \$1,400.

The ratio of the relative costs for detecting a 5% change in breast volume using the Grossman–Roudner cone, cast, and MRI is 1:64–189:373–33,500 (1:127:16,967, the mean of these ratio changes). Because these ratio ranges do not overlap, the Grossman–Roudner breast-measuring device clearly offers the most cost-effective method for determining changes in breast volume in studies testing topical therapies used to change breast size.

Discussion

Several methods have been proposed for the measurement of breast volume, but no cost-effectiveness evaluation comparing methods has been performed.

Anatomic measures to fit brassieres, water displacement, casting, the Grossman–Roudner cone, photography, mammograms, ultrasound, and MRI all have been suggested as methods for measuring breast volume.

Anatomic measures such as those used to fit brassieres are inaccurate for measuring breast volume because of variability in breast shape [1]. Cup size typically is determined by the difference in the circumferences of the chest at the submammary crease and the nipple line. This measurement varies considerably as breasts become ptotic. Brassiere sizes also are inaccurate because cup size varies with each brand.

Water displacement based on Archimedes' principle is another way of determining breast volume. The subjects had difficulty performing this test because the breast tissue, composed of fat tissue, floated [1]. Variability of this measurement, attributable to different levels of submergence, was therefore common, and the measurement's wide variability made it inaccurate [8].

The casting method for determining breast volume has been tested by measuring both breasts at the same time. A study carried out by Campaigne et al. [2] using plaster strips applied horizontally across both breasts to measure the volume of both breasts gave an error of $\pm 10.2\%$, attributable to variability in creating the casts and variability in filling the casts with sand, resulting in large within-subject variability. To observe the variability in filling the casts of the breast pairs with sand, the same person filled 30 randomly selected casts twice 30 min apart. It was estimated that half of the error resulted from filling the cast with sand. Campaigne et al. [2], however, found that the reproducibility improved after the filling had been repeated 10 times.

In another study analyzing breast volume measurements by Bulstrode et al. [1], thermoplastic sheets were used as the casting material, and only a single breast was measured. These researchers noted no distinguishable disadvantages in using the casting method to measure breast volume. A visual model of the breast was used to evaluate the shape, and the thermoplastic molding was a convenient and well-tolerated method for the subjects. Therefore, in our study, we decided to determine the breast volume of a single breast using a casting method.

The Grossman–Roudner breast-measuring device was developed as an easy, precise, cost-effective method for determining breast volume [3]. This method has been compared with the casting method, and the Grossman–Roudner cone proved to be reproducible [5]. Jack Grossman, the developer of the Grossman–Roudner breast-measuring device, stated that this method is “simple and direct and by no means absolute in its volume determination for breasts” [5]. He further explained that this technique provides a relative reproducibility that is

Table 2. Relative number and cost to detect a 5% change in breast volume according to mean cup size

	AA	A	B	C	D
Cone	162 ± 3	171 ± 6	290 ± 10	342 ± 14	493 ± 23
<i>N</i> for 5% change	4	10	9	13	15
\$ for 5% change	4	10	9	13	15
Cast	247 ± 11	283 ± 32	405 ± 33	539 ± 50	708 ± 64
<i>N</i> for 5% change	13	82	85	56	54
\$ for 5% change	260	1,640	1,700	1,120	1,080
MRI	389 ± 48	467 ± 4	490 ± 19	541 ± 16	959 ± 16
<i>N</i> for 5% change	96	3	11	7	4
\$ for 5% change	134,400	4,200	15,400	9,800	5,600

MRI, magnetic resonance imaging.

helpful for aesthetic purposes [5]. As a result, we chose to use the Grossman–Roudner breast-measuring device for our study on measuring breast volume.

Spectrophotography gives the volume measurements and the relative size relationship of normal breast pairs. We are interested only in breast volume. Costly equipment is necessary for performing the necessary stereophotogrammetry, and it is a very time-consuming process. In a study performed by Loughry et al. [4] using this method, wide-angle stereometric cameras, a surface contrast optical projector, and a double-rail support were required [4]. The stereocameras were equipped with biogon lenses, vacuum film platens to ensure film flatness, and fiber optic bundles that placed fiducial marks on the exposed film. In addition, production of the total breast volumes for the subjects required the use of several mathematical algorithms. A drawback to using photography as a breast volume measurement is the skill required by the person using the stereometric cameras, the cost of the associated equipment, and the necessary expertise for using the mathematical algorithms.

Mammography, ultrasound, and MRI use similar principles in measuring the volume of the breast by indirect visualization techniques. Findings have shown breast volumes determined by mammography to have good correlation with breast volumes measured at a subsequent mastectomy for removal of a malignant tumor [1]. Mammography, however, involves the risk of radiation exposure, which is difficult to justify for cosmetic applications. Mammography also is more uncomfortable for the subject than the other measurement methods in this group [1]. Although ultrasound and MRI use a similar principle to measure breast volume, the use of magnetic resonance gives much better separation of tissue planes and better definition of the breast tissue than the use of ultrasound. Therefore, we chose to evaluate magnetic resonance as the best measurement for representing this group of methods.

Of the various methods available to measure breast volume, we selected two anatomic measures and one indirect measure for evaluation as having the best qualities for cosmetic applications: the Grossman–Roudner cone, breast casting, and MRI. We expected that MRI would give the most accurate and precise estimation of breast volume. We expected that the Grossman–Roudner cone would not have sufficient accuracy because the device does not contain the entire breast tissue within the cone. We expected that the breast casting would be the most cost-effective measure because it measured the entire breast and is much less expensive than MRI.

To our surprise, the Grossman–Roudner cone was clearly the most cost-effective measure. Although the entire breast is not contained in the cone during measurement, the reproducibility of the measure was comparable with that for MRI. Therefore, the Grossman–Roudner cone appears to be the most cost-effective and preferred measure for estimating change in breast volume during a cosmetic treatment program to alter breast size.

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References

1. Bulstrode N, Bellamy E, Shrotria S: Breast volume assessment: Comparing five different techniques. *Breast* **10**:117–123, 2001
2. Campaigne BN, Katch VL, Freedson P, Sady S, Katch FI: Measurement of breast volume in females: Description of a reliable method. *Ann Hum Biol* **6**:363–367, 1979
3. Grossman AJ, Roudner LA: A simple means for accurate breast volume determination. *Plast Reconstr Surg* **66**:851–852, 1980
4. Loughry CW, Sheffer DB, Price TE Jr, Lackney MJ, Bartfai RG, Morek WM: Breast volume measurement

- of 248 women using biostereometric analysis. *Plast Reconstr Surg* **80**:553–858, 1987
5. Palin WE Jr, von Fraunhofer JA, Smith DJ Jr: Measurement of breast volume: Comparison of techniques. *Plast Reconstr Surg* **77**:253–255, 1986
 6. Pechter EA: A new method for determining bra size and predicting postaugmentation breast size. *Plast Reconstr Surg* **102**:1259–1265, 1998
 7. Soutter WP, Hanoch J, D'Arcy T, Dina R, McIndoe GA, DeSouza NM: Pretreatment tumour volume measurement on high-resolution magnetic resonance imaging as a predictor of survival in cervical cancer. *BJOG* **111**:741–747, 2004
 8. Tezel E, Numanoglu A: Practical do-it-yourself device for accurate volume measurement of breast. *Plast Reconstr Surg* **105**:1019–1023, 2000