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ORIGINAL ARTICLE

Breast volume assessment: comparing five different techniques

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SUMMARY. Breast volume assessment is not routinely performed pre-operatively because as yet there is no accepted technique. There have been a variety of methods published, but this is the first study to compare these techniques.

We compared volume measurements obtained from mammograms (previously compared to mastectomy specimens)[1] with estimates of volume obtained from four other techniques: thermoplastic moulding, magnetic resonance imaging, Archimedes principle and anatomical measurements. We also assessed the acceptability of each method to the patient. Measurements were performed on 10 women, which produced results for 20 breasts.

We were able to calculate regression lines between volume measurements obtained from mammography to the other four methods: (1) magnetic resonance imaging (MRI), $379 + (0.75$ MRI) [$r = 0.48$], (2) Thermoplastic moulding, $132 + (1.46$ Thermoplastic moulding) [$r = 0.82$], (3) Anatomical measurements, $168 + (1.55$ Anatomical measurements) [$r = 0.83$]. (4) Archimedes principle, $359 + (0.6$ Archimedes principle) [$r = 0.61$] all units in cc.

The regression curves for the different techniques are variable and it is difficult to reliably compare results. A standard method of volume measurement should be used when comparing volumes before and after intervention or between individual patients, and it is unreliable to compare volume measurements using different methods.

Calculating the breast volume from mammography has previously been compared to mastectomy samples and shown to be reasonably accurate. However we feel thermoplastic moulding shows promise and should be further investigated as it gives not only a volume assessment but a three-dimensional impression of the breast shape, which may be valuable in assessing cosmesis following breast-conserving-surgery. © 2001 Harcourt Publishers Ltd

INTRODUCTION

Breast volume assessment is not generally performed before surgery for benign conditions, but would be of value in breast asymmetry, as in Poland's syndrome, breast reduction, or in reconstructive breast cancer surgery. While a number of methods of measuring breast volume have been described, this is the first study to compare different techniques.

The method of obtaining measurements from mammograms[1] and comparing them to the volume of mastectomy specimens produces a good correlation between specimen volume and calculated volume.

Other methods described in the literature include casting techniques using either fast-setting plaster or thermoplastic sheets[2] producing a negative replica that is subsequently measured.

Ultrasound has been used in studies into oral contraceptive use[3] by scanning the breast in 1 cm longitudinal and transverse slices, the sum of which gives a volume. Magnetic resonance imaging[4] has been used in assessing changes in breast volume and composition during the menstrual cycle. Computerized measurement of the breast has been performed during investigation of human milk synthesis.[5] This involved the projection of horizontal light stripes onto the breast, giving a contour map like image that was captured by a charge couple device (CCD) camera and the volume calculated from a computer-generated image of the breast.

A number of devices have been developed as measuring tools. A method applying the Archimedes principle[6] involving the displacement within a large calibrated cylinder has been used to assess volume

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before reconstructive breast surgery. Another device is an adjustable cone,[7] which changes to the size of the breast and the volume is read off a scale. A set of graduated discs[8] are available but have a number of drawbacks: firstly they only work for breasts of less than 425 cc, and secondly if the breasts are too firm the device overestimates the volume.

A study measuring 125 Chinese women[9] made direct anatomical measurements of the breast and chest wall, and used a formula for the breast volume.

In view of the wide variation in methods, this study was undertaken to compare five techniques in order to evaluate their suitability.

AIM

Results of volume measurements obtained from mammography were compared with estimates of volume obtained from four other techniques: (1) thermoplastic moulding,[2] (2) magnetic resonance imaging, (3) Archimedes principle and (4) anatomical measurements.[10] We also assessed the acceptability of each method to both the patient and clinician.

METHOD

Study group selection

The study group was selected from patients who attended the breast clinic. The 10 patients had all been seen in the clinic, underwent mammography and were diagnosed as having benign conditions that did not require surgery. They were then informed and consent was given for the study. Each subject underwent all modalities of breast volume measurement except for one patient who declined to undergo MRI scanning. Each patient graded the acceptability of the separate methods using a score sheet. The average age of patients was 48 (38–68), eight pre-menopausal and two post-menopausal. The pre-menopausal women had measurements taken at the same time of the menstrual cycle.

Mammography

The breast volume was calculated by taking measurements from the cranio-caudal mammogram and using the formula for the volume of a cone (i.e. $1/3\pi r^2 h$) where r is half the length of the base of the breast and h is the distance from the nipple to base.[1] Figure 1 shows a mammogram with dimensions marked.

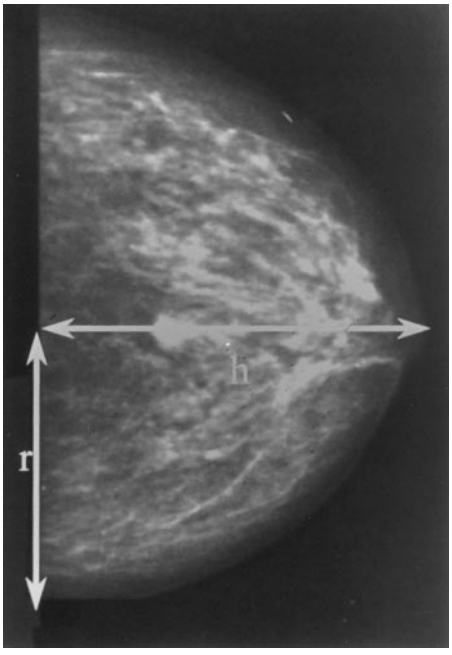

Fig. 1 Mammogram with dimensions.

MRI

Volume measurements were made using a 0.5 Tesla GE max. Sagittal slices of 7 mm or 8 mm were taken of the breast. The regions of interest were then drawn for each slice and the volumes in cubic centimetres were estimated. The whole breast volume was then calculated as the sum of the individual slice volumes. All measurements were made by one radiographer to ensure uniformity of method, and checked by a consultant radiologist. Figure 2 shows a MRI of an outlined breast slice.

Thermoplastic cast

A cast of the breast is made using a perforated 2 mm thermoplastic sheet (Orfit^{TM} by Promedics, Blackburn, Lancs). The sheets were heated to 55°C in a water bath until pliable and when at a comfortable temperature, were moulded onto the breast and chest wall. The cast cools and keeps its shape; the volume of the negative replica is then measured[2] by laying cling film into the mould to obliterate the perforations and filled with water. The casting was performed by one person and checked by a second. Figure 3 shows a thermoplastic sheet before and after moulding.

Archimedes principle

This method involves the use of a calibrated container, filled to the top with water at body temperature. The

Fig. 2 MRI with outlined sagittal breast slice.

patient was asked to place her breast into the container, ensuring good contact between the chest wall and the container edge. The volume of the water displaced was measured. This was repeated three times to get an average volume for each breast.

Anatomical measurements

Measurements are taken from the:

1. Nipple to the medial border (MR)
2. Nipple to the lateral border (LR)
3. Medial and lateral extent of the breast
4. Nipple to inframammary fold (IR) and mammary projection (MP), which is measured from the sternum to the nipple by viewing the patient from the lateral aspect.

The breast volume is calculated using the formula $V = 1/3\pi \times MP^2 \times (MR + LR + IR - MP)$.[9]

Figure 4 shows the dimension (MR, LR, IR) measured on a patient's breast. Mammary projection is measured from the sternum to the nipple by viewing the patient from the lateral aspect.

Acceptability score

The patient assessed each method using a score from scale of one to five (1 – highly acceptable, 2 – acceptable, 3 – tolerable, 4 – barely tolerable, 5 – unacceptable).

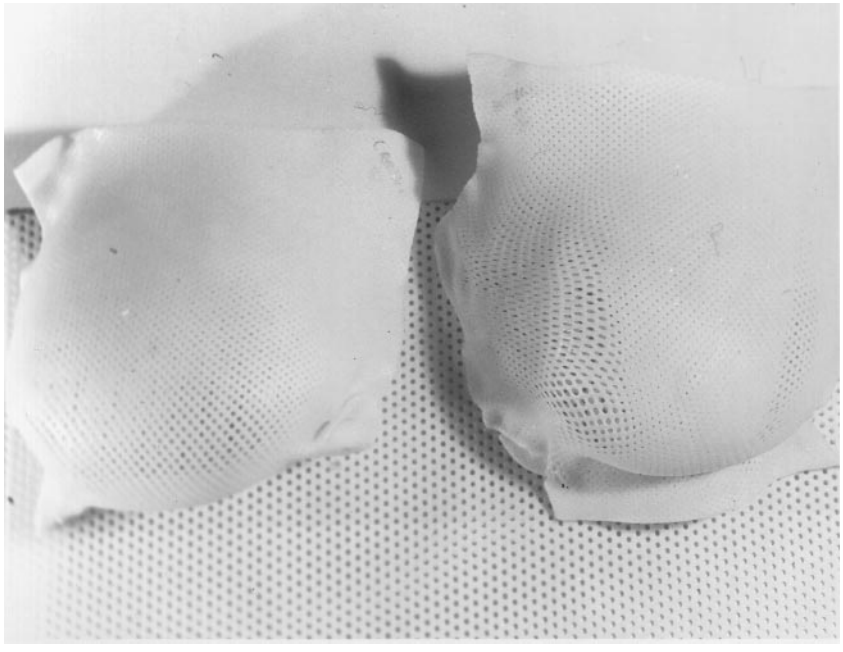

Fig. 3 Thermoplastic sheet before and after moulding.

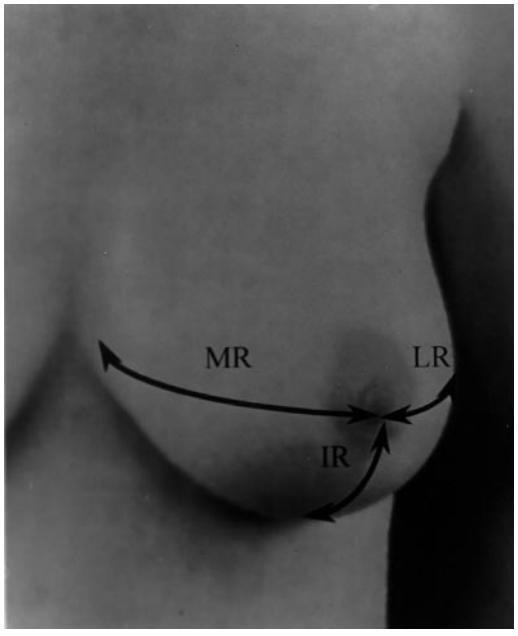

Fig. 4 Dimensions (MR, LR, IR) measured on patients breast. Mammary projection is measured from the sternum to the nipple by viewing the patient from lateral.

Statistical analysis

Mammographic assessment of breast volume was compared to the other four methods and linear regression equations, and correlation coefficients, r, were calculated.

RESULTS

Breast volume measurements made from anatomical measurements, MRI, thermoplastic moulding and Archimedes principle were compared directly with mammogram-assessed volumes. These were performed on 20 breasts (10 women).

The regression coefficients, the slope of the regression line, and a comparison of the volumes derived from the mammogram to the other four methods were produced. The correlation coefficient, r, is the index of association between variables x and y. It varies between $+1$ to -1. When $r=0$ there is no correlation. When $r=+1$ the correlation is said to be complete and perfect. When $r=-1$ there is complete negative correlation.

Anatomical measurement

The values for mammogram and anatomical measurement derived volumes are given in Figure 5.

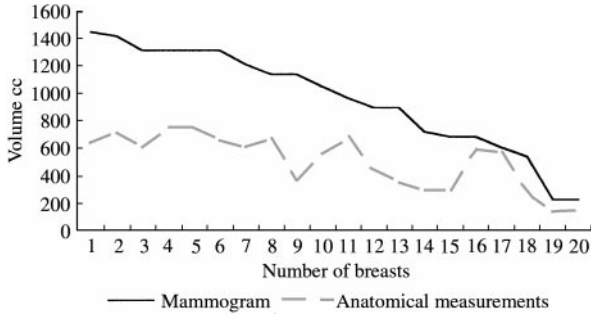

Fig. 5 Volume measurements comparing mammogram and anatomical measurement techniques.

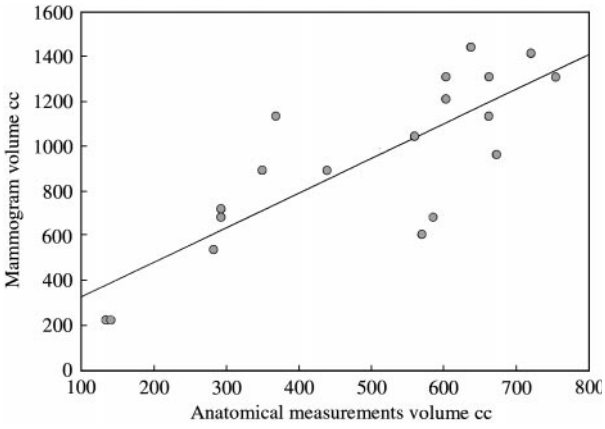

Fig. 6 The regression curve for anatomical measurement against mammogram-derived volumes (cc).

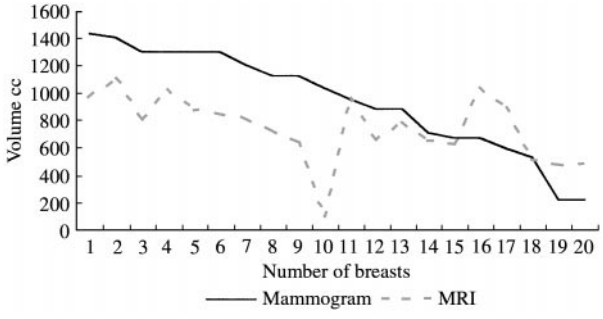

Fig. 7 Volume measurements comparing mammogram and MRI techniques.

The regression coefficient is as follows (Fig. 6):

$1.55 \times$ anatomical measurement volume $+ 168$ = mammogram volume

The correlation coefficient is $r=0.830$.

MRI

The values for mammogram and MRI derived volumes are given in Figure 7.

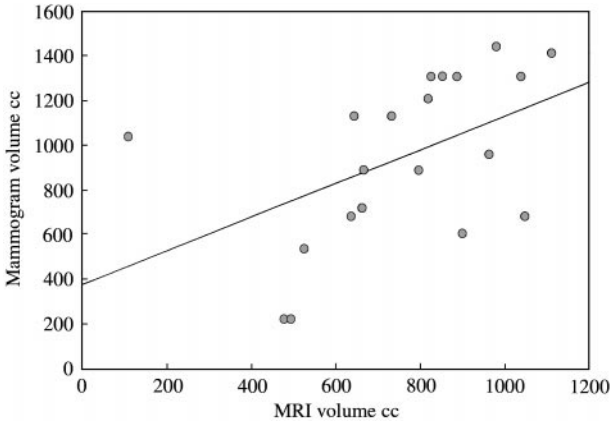

Fig. 8 The regression curve for MRI against mammogram derived volumes (cc).

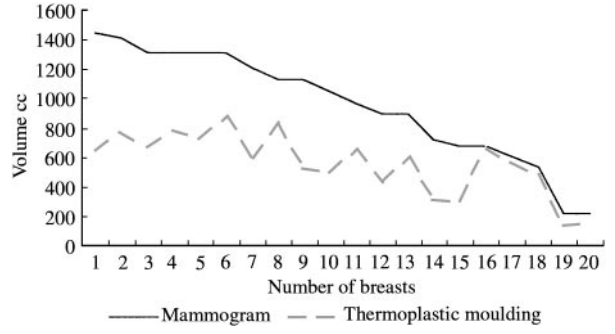

Fig. 9 Volume measurements comparing mammogram and thermoplastic moulding techniques.

The regression coefficient is as follows (Fig. 8):

$$0.75 \times \text{MRI volume} + 379 = \text{mammogram volume}$$

The correlation coefficient is r = 0.48.

Thermoplastic moulding

The values for mammogram and thermoplastic moulding derived volumes are given in Figure 9.

The regression coefficient is as follows (Fig. 10):

$$1.46 \times \text{thermoplastic moulding volume} + 132 = \text{mammogram volume}$$

The correlation coefficient is r = 0.82.

Archimedes principle

The values for mammogram and Archimedes principle derived volumes are given in Figure 11.

The regression coefficient is as follows (Fig. 12):

$$0.60 \times \text{Archimedes principle volume} + 359 = \text{mammogram volume}$$

The correlation coefficient is r = 0.608.

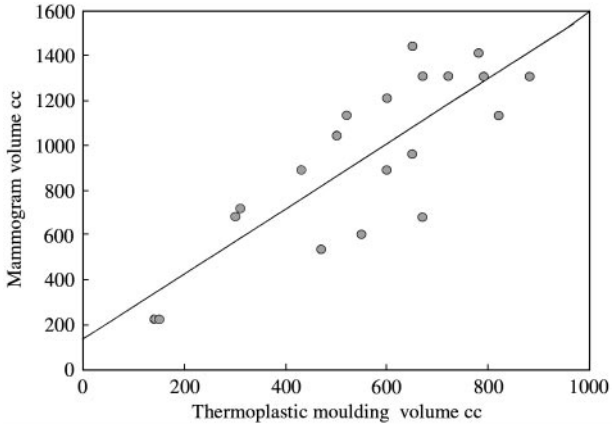

Fig. 10 The regression curve for thermoplastic moulding against mammogram derived volumes (cc).

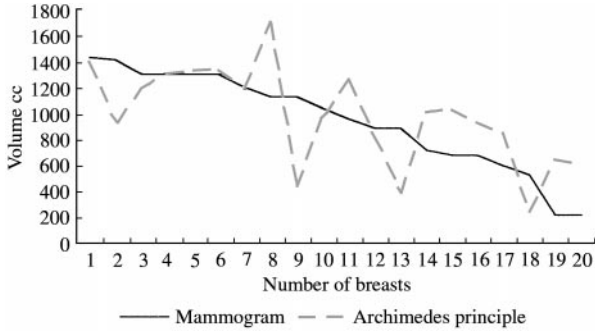

Fig. 11 Volume measurements comparing mammogram and Archimedes principle techniques.

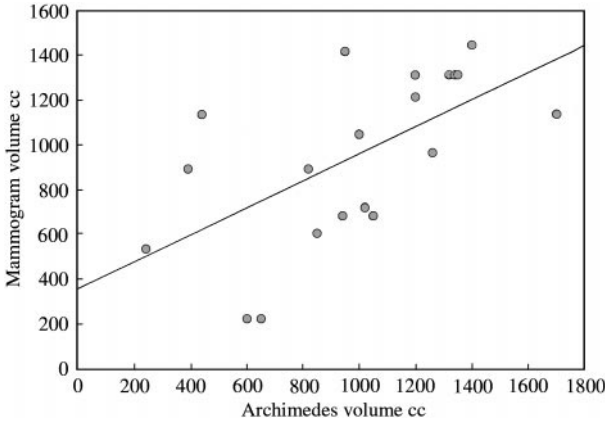

Fig. 12 The regression curve for Archimedes principle against mammogram derived volumes (cc).

Acceptability score

A 5-point scoring system was used for patient and clinician satisfaction in performing the measurements

(1 – highly acceptable, 2 – acceptable, 3 – tolerable, 4 – barely tolerable, 5 – unacceptable), the results of which are given in Table 1.

The advantages and the disadvantages of the various methods are listed in Table 2.

DISCUSSION

A number of methods have been described to assess breast volume measurement, but only mammographically derived volume has been compared to mastectomy sample volumes. This study is the first to compare five different breast volume measuring techniques on 20 individual breasts. Our results, although only derived from 20 breasts, show that various methods of estimation give differing results for the volume of each breast. The advantages and disadvantages of each method have been evaluated. Anatomical measurements were easy to make and well tolerated by the patients, however there are arguments and uncertainty over the mathematical formula for breast volume used with this method.

Patients gave a favourable acceptability score for the water displacement method based on Archimedes principle, but some of the patients had difficulty in performing the test adequately.

Magnetic resonance imaging (MRI) examination of breast pathology has been shown to be extremely valuable in the differentiation between scars and recurrent malignancy that is often impossible with mammograms.[10–11] The MRI assessment was well tolerated apart from one patient who suffered from claustrophobia. Presently the cost of scanning and the time it took for the assessment of results was high, making its use unrealistic at this time, but both this will with improved equipment and software.

Calculating the volume from mammography has previously been compared to mastectomy samples and has therefore been the method of choice. Measurements from the mammogram were simple and could be done without the patient being present. Mammography is also essential in the process of diagnosing malignant disease, but in benign conditions such as Poland syndrome or breast asymmetry mammography, it is not required. This was the least well tolerated of the techniques but as a mandatory part of assessing malignant breast disease this disadvantage was discounted.

Thermoplastic moulding was a convenient and well-tolerated method. The other advantage is that one had a model of the breast to compare shape. There were no notable disadvantages.

We have developed formulae (based on linear regression) to convert the volume estimated by various methods to the mammographic measurement of breast volume. Owing to the variability in regression coefficients for the different techniques, it is difficult to reliably compare results. We feel that a standard method of volume measurement is recommended to reduce variability. We feel that the same method should be used when comparing volumes before and after intervention or between patients, and that it is unreliable to compare volume measurements between different methods. It is difficult to understand why there is such a variation in results derived from different methods apart from the fact that they are all assessing subtly different parts. It would therefore be useful to perform a prospective trial measuring breast volumes by different methods in patients undergoing mastectomy.

Table 1 Acceptability score

Test	Acceptability score	
	Patient	Clinician
MRI	2	3
Mammogram	4	2
Archimedes	2	3
Moulding	2	1
Anatomical	1	1

CONCLUSION

We feel volume assessment by Archimedes principle should not be used despite its acceptability, as patients had difficulty in performing the test adequately. MRI is

Table 2 Advantages and disadvantages of the various techniques

Test	Advantages	Disadvantages
MRI	Diagnosis (scarring vs malignancy)	High cost Claustrophobia (one patient)
Mammogram	Diagnostic importance	Uncomfortable for patient
Archimedes		Patients had difficulty performing the test
Moulding	Visual model	
Anatomical	Ease of performance	Formula is unreliable

too expensive to be performed as a routine investigation but its use will increase as the price comes down and its usefulness in differentiating benign and malignant disease increases. The use of anatomical measurements is open to criticism because of arguments over the formula for the shape and volume of a breast. Mammographically derived volume has previously been compared to mastectomy samples and has therefore been the method of choice. However we feel that the use of thermoplastic moulding shows promise and should be further investigated as it not only gives a volume assessment but also a three-dimensional impression. This study answers some of the questions regarding volume assessment, but further work comparing these methods to mastectomy samples would be beneficial.

Acknowledgement

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