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Review

The accuracy of breast volume measurement methods: A systematic review

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A B S T R A C T

Breast volume is a key metric in breast surgery and there are a number of different methods which measure it. However, a lack of knowledge regarding a method's accuracy and comparability has made it difficult to establish a clinical standard. We have performed a systematic review of the literature to examine the various techniques for measurement of breast volume and to assess their accuracy and usefulness in clinical practice. Each of the fifteen studies we identified had more than ten live participants and assessed volume measurement accuracy using a gold-standard based on the volume, or mass, of a mastectomy specimen. Many of the studies from this review report large (>200 ml) uncertainty in breast volume and many fail to assess measurement accuracy using appropriate statistical tools. Of the methods assessed, MRI scanning consistently demonstrated the highest accuracy with three studies reporting errors lower than 10% for small (250 ml), medium (500 ml) and large (1000 ml) breasts. However, as a high-cost, non-routine assessment other methods may be more appropriate.

Introduction

Breast volume has been identified as a key metric [1] in breast surgery [2,3]. As a clinically relevant [4] objective measure, knowledge of breast volume helps a surgeon to select protocols, choose appropriate implant sizes [5] and achieve breast symmetry [6]. It can be used to plan aesthetic [3,7–13] and breast conservation surgeries [7,9,12,14–19] and in the diagnosis of breast oedema [20,21]. The use of breast volume may lead to reductions in repeat surgeries (around 1 in 3 women in the UK are not satisfied with aesthetic outcome [22]) and better diagnosis of breast oedema.

The breast is a three-dimensional (3D) structure and difficult to assess accurately. Variations in patient pose [23], breast shape [2] and in identifying the breast boundary [24] (external and posterior chest wall) cause variability in volume measurement.

Several methods have been proposed to assess breast volume through the use of medical imaging technology [25], devices based on geometric measurement [26], water displacement techniques [27–29] and breast casts [30,31]. There is no 'accepted' technique for measurement of breast volume due to a lack of clear information regarding the accuracy and comparability of each method. This has limited the use of breast volume measurement methods in routine clinical practice. Large errors negatively impact a surgeon's ability to determine, for example, the appropriate size of breast implant or the quantity of tissue to be removed. In addition, ease of use, cost and complexity [12] cannot be dismissed.

Many advocates of particular methods of volume measurement describe them as 'accurate' without assessing or quantifying error [26,27,29,30]. Several authors have, however, made comparisons to determine accuracy. We performed a systematic review of the literature to examine the various techniques for measurement of breast volume and to assess their accuracy and usefulness in clinical practice.

Two other systematic reviews which assess breast volume measurement have been identified. Xi et al. [46] reviewed methods of breast measurement (volume, shape and surface area) with regards to cost, suitability and accuracy. However, accuracy was not dealt with in detail (focussing on reliability as the coefficient of variation) and papers were not excluded based on the quality of gold-standard. O'Connell et al. [47] focused on 3D surface imaging methods used in breast volume assessment (referred to as 3D

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scanning in this study). While accuracy is discussed, other methods of volume measurement are not considered.

Due to the difficulties in finding a consistent method of assessing accuracy, Xi et al. proposed to assess a method's potential for accurate measurement by its definition of the external breast boundary and the internal posterior wall. According to this assessment they identified 3D scanning, MRI and CT methods as being most ‘accurate’.

In this review we have focused on accuracy with regards to error and uncertainty of measurement. By identifying an established gold-standard, obtaining studies' data and performing data simulation we have been able to numerically quantify the error and uncertainty of eight different methods of breast volume measurement.

Methods

Search strategy

A search strategy combining the title/abstract words (“breast volume” OR “breast shape”) in proximity to the title/abstract words (measur* OR accura* OR valid* OR estimat*) was used to locate all papers relating to breast volume measurement. The searches were run in the following databases from their inception to Dec, 2014: CINAHL Plus with Fulltext (via EBSCOHost), The Cochrane Library (Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Clinical Trials (CENTRAL)), Database of Abstracts of Reviews of Effects (DARE), Cochrane Methodology Register (CMR), Health Technology Assessment Database (HTAD), and NHS Economic Evaluation Database (NHS EED), Embase (via NHS Evidence Search), IEEE Xplore, Medline (via EBSCOHost), Scopus (Elsevier), SPORTDiscus (via EBSCOHost), Web of Science (all Databases).

Additionally, the British Library Main Catalogue (http://explore.bl.uk/) was searched using the strategy: Main Title contains “breast volume” OR “breast shape” AND Abstract contains accura* OR measur* OR valid* OR estimat*/All materials, all dates.

We checked the reference lists from eligible studies to identify further relevant studies. Citation (forwards) searches were also carried out on included studies to identify further relevant studies.

Data collection

All citations were organised in RefWorks software and duplicates were removed. Remaining records were compiled into a Microsoft Access database within which remaining study selection was independently performed by SC and JW.

In the title/abstract screening, records were included if it was evident that breast volume was measured and a measure of accuracy/validity was taken. The remaining records proceeded to full review, where the papers were judged against the following inclusion criteria:

1. Accuracy of breast volume is assessed
2. At least ten participants included in the study
3. Human participants used (no mannequins or phantom breast objects)
4. Published, peer-reviewed study
5. A suitable ‘gold-standard’ was used – the volume or mass of resected breast tissue (or fluid)

All studies which met the inclusion criteria proceeded to data extraction.

Data extraction

Information was extracted independently by SC and JW using predefined fields. Specifically, the type of gold-standard, number of participants, range of data, the comparator breast volume measurement method(s), the statistical method(s) of assessing accuracy and the associated value(s).

Because the objective of the review was to establish the accuracy of volume measurement, additional raw data were sought using three methods: directly from the publication (full disclosure in a results table), directly from the authors (for publication dates within 10 years) and extraction from published figures (when possible, using image processing). Two authors published the entirety of their data [32,33] in data tables, which was used in further statistical analyses. Two authors sent us their original datasets [12,34] and in two studies [35,36] data was obtained by calculating the position of plotted data points using image processing techniques. The centroids of each data point were obtained from digital images (in image co-ordinates) and these were transformed to scaled data values by calculating the scale from the X and Y axes.

Data analysis

As an intuitive representation of a method's accuracy we used a linear regression to calculate expected error at three different breast volumes: 250, 500 and 1000 ml – representing the typical range from studies in this review. The uncertainty of each measurement at these values was not assessed – it was not given in the majority of cases.

For raw data obtained, we performed a Bland–Altman analysis [37] to calculate the limits of agreement and linear regression in order to model measurement error at different breast sizes. In cases where proportional error was apparent, the data were de-trended prior to Bland–Altman analysis, in cases where heteroscedasticity was apparent, the Bland–Altman data were processed as percentage values (and is presented as such).

A large number of studies reported correlation coefficients. To gain further insight we used Monte-Carlo simulation to estimate measurement uncertainty. We used the r value, number of samples and range of the data in the following way. Assuming error was normally distributed and homoscedastic, we created 1000 randomly generated datasets *for each study*. Each dataset had the same number of data points and nominal-range as the study it represented. In each case we adjusted the standard deviation of the error until the Pearson's r of each simulated data-set matched reported values (results are presented in Table 2). This gave an estimate of the 95% confidence intervals of each measurement.

At all stages, any disagreements were discussed and consensus reached through a discussion/investigation of the literature.

Results

See Fig. 1 for a document flow chart. The database searches yielded 701 records, and 238 unique records after removing duplicates. After title/abstract screening, 71 records proceeded to full-text screening, from which 13 records met the inclusion criteria. A further 2 records were identified from reference and citation searches, resulting in 15 studies for this review.

Table 1 summarises the results presented in the studies included in this review. The measurement method, and studies which assessed it, are identified. For each study we present the gold standard used (volume or mass), the size of the study (n) and all available information regarding accuracy. Accuracy information is split into three categories: mean error ± 1.96 standard deviations,