Asymmetry of Inframammary Folds in Patients Undergoing Augmentation Mammaplasty

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Abstract
Background: Variation in the anatomical position of the inframammary fold (IMF) in women remains poorly studied.
Objectives: The purpose of this study was to evaluate the incidence of asymmetry between IMF locations on the chest wall of women undergoing breast augmentation and to determine breast measurements associated with IMF asymmetry.
Methods: Three-dimensional imaging analysis of the breasts was performed in 111 women with micromastia, using the Vectra Imaging SystemTM. The following measurements were recorded: vertical distance between right and left IMF (inter-fold distance), vertical distance between nipples (inter-nipple distance), and difference between projection of right and left breasts in anterior-posterior direction.
Results: Asymmetry between the right and left IMF positions was found in the majority of patients (95.4%), with symmetry only found in 5 patients (4.6%). In the majority of patients (60.3%), the right IMF was located inferior to the left IMF with median inter-fold distance 0.4 cm (range, 0.1, 2.1 cm). In 39 patients (35.1%), the left IMF was located inferior to the right with median inter-fold distance 0.4 cm (range, 0.1, 1.7 cm). There was strong correlation between the degree of asymmetry of IMF and asymmetry of nipple areola complex (NAC) positions ($r = 0.687, P < .01$).
Conclusions: The majority of women with micromastia demonstrate asymmetry of the IMF, which correlates with asymmetry of NAC location. The authors propose a classification system based on most commonly observed IMF locations as types I (right IMF inferior to left), type II (left IMF inferior to right) and type III (both IMF located on the same level).

Level of Evidence: 4

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Documenting morphologic differences between a woman’s own breasts has been a subject of multiple previous studies. Identification of pre-existing breast asymmetry in a patient undergoing breast surgery aids the surgeon in developing a precise operative plan, which accounts for these differences in order to optimize symmetry and obtain an ideal surgical outcome. Detailed discussion between a patient and her surgeon about identified breast asymmetries is a critical part of the pretreatment consultation. Educating patients about these pre-existing asymmetries allows a more comprehensive understanding of surgical goals, patient involvement in the surgical planning process, and appropriate expectations for surgical outcomes. Especially in women undergoing augmentation mammaplasty, pretreatment identification of even subtle asymmetries between the breasts is imperative, as the procedure frequently accentuates awareness of these asymmetries postoperatively, potentially leading to patient dissatisfaction about aesthetic outcomes. As a result, even minimal discrepancies in shape and volume in a patient’s own breasts that may have been unrecognized in pretreatment may become noticeable after the procedure. Several
studies have previously investigated the extent of breast asymmetry in women undergoing augmentation mammoplasty and have universally demonstrated, despite variation in measurement techniques, the presence of asymmetry of various breast measurements.\textsuperscript{4,5} Women with micromastia have previously been documented to have asymmetry in breast volume, projection from the chest wall, position of nipple areola complex (NAC), areola diameter, and length of key breast anthropometric distances including sternal notch to nipple and nipple to inframammary fold.\textsuperscript{4} However, despite multiple previous anthropometric evaluations of breast landmarks in the existing surgical literature, asymmetry of inframammary fold (IMF) has received little attention.

The IMF remains one of the critical breast anatomical structures, which determines width of each breast and position of mammary glands on the chest wall.\textsuperscript{6,7} This is an especially critical landmark in breast surgery, where unevenly positioned IMF in the vertical plane (uneven IMF “height”) may result in an asymmetric appearance of a woman’s breasts. Therefore, a pretreatment examination of IMF for presence of asymmetry is critical for planning augmentation mammoplasty.

The primary goal of this study was to evaluate the incidence of symmetry of patients’ IMF locations in women undergoing breast augmentation. The study additionally sought to determine anthropometric breast parameters associated with IMF asymmetry.

\section*{METHODS}
Medical records and clinical images of 111 consecutive female patients who underwent evaluation for primary augmentation mammoplasty from October 2011 to November 2014 by the senior author (GPM) were retrospectively reviewed. Data was analyzed following approval by the Vanderbilt University Institutional Review Board. All patients underwent digital imaging of the chest with 3D digital reconstruction and anthropometric analysis of breast parameters using the Vectra M3 Imaging System software (Canfield Scientific Inc., Fairfield, New Jersey). Patients with a previous history of breast surgery were excluded from the study. Standard anthropometric breast measurements analyzed by the Vectra M3 Imaging System was based on a surface measurement between two landmarks, one placed on the nipple and the second placed on the chest-breast interface (point of transition between the breast mound and the chest wall). These landmarks were located with feature detection algorithms for the 3D image’s surface shape and texture color. Projected IMF is marked as a reversed arcuate line reflecting identified as the breast to chest transition line. Quantitative analysis of the NAC position in the vertical plane (NAC height) was performed by measuring the distance between centers of the right and left nipples on the vertical axis (vertical inter-nipple distance, Figure 1B). Quantitative analysis of differences in breast projection was performed by comparing the distance between the most prominent points of the right and left breasts in an anterior-posterior direction (Figure 1C). In all cases, symmetry was considered to exist only if the difference of measurements between sides equaled 0 mm.

Chest wall asymmetry was assessed by analyzing digitally reconstituted images of an anterior chest wall projection (Figure 1D). Categorical variables were used to record either equivalent projection of a patient’s chest wall (symmetric) or greater projection of either the right or left sides. Approximate volumes of each breast and differences between volumes of a patient’s breasts were calculated by the program software and recorded.

Breast parameters and patient variables were compared by two-tailed Student, Fisher’s exact, or by Chi-square tests, as appropriate. A two-tailed Student \textit{t}-test set for a type I error of 5\% (alpha = .05) was done to determine significance for continuous variables. Pearson’s correlation coefficient was done to assess the relationship between continuous variables. One sample Student \textit{t}-test was done to test null hypothesis, which assumes that distribution of the length of interfold distance in all cohort of samples is random. For this purpose, interfold distance in patients with left IMF located inferior to right IMF was assigned negative values. All analyses were performed using SPSS 17.0 statistical software (SPSS Inc., Chicago, IL).

\section*{RESULTS}
\subsection*{Breast Anthropometrics}
Median age of women presenting for augmentation mammoplasty was 33-years-old (range, 18 to 49 years). A standard patient breast morphogram with recorded breast measurements is demonstrated in Figure 1. Median and range values of measured breast parameters of patients included in this study are listed in Table 1. The measured breast parameters in the study patients did not demonstrate statistically significant differences between right and left breasts with the
exception of BW, which was greater in patients’ right breasts (Table 2). Prevalence of asymmetry in standard breast anthropometric values is demonstrated in Table 3. There were no patients in this cohort who had equivalent right and left breast measurements in all recorded parameters (no absolutely symmetric breasts). Only a small proportion of patients (range, 0%-8%) demonstrated symmetry in a single breast value on both sides.

The majority of patients exhibited different degrees of asymmetry in each recorded parameter. Patients tended to have longer SNN and CN lengths in left breast, whereas length of NIMF was found to have more equal distribution (Table 3). In 63% of patients, the base of right breast tended to be wider compared to the left breast. A larger proportion of women had a greater parenchymal volume in the left breast compared to the right breast (58% vs 43% respectively). There were no patients with equivalent breast volume in both breasts.

### IMF Asymmetry

Breast morphograms with anatomical variants of IMF locations encountered in the study are illustrated in Figure 2. IMF locations recorded include: right IMF located more...
inferior to the left fold, left IMF located more inferior to the right fold and both IMF located at the same level. The distribution of types of IMF positions encountered in the entire cohort is demonstrated in Figure 3. The majority of women (95.4%) in this study had asymmetric IMF positions. Only 4.6% of patients ($n = 5$) had symmetric IMF positions in the vertical plane. The most common type of IMF relationship seen was asymmetric, with the right IMF located inferior to the left one (60.3%, $n = 67$) with median inter-fold distance of .4 cm (range, .1, 2.1 cm). The second most common anatomic variant of IMF position was the left IMF located inferior to the right fold (35.1%, $n = 39$) with median inter-fold distance of .4 cm (range, .1, 1.7 cm). In women who demonstrated asymmetry (95%), the interfold distance ranged from .1 to 2.1 cm. Variations in the interfold distance are demonstrated in Figure 4, which demonstrates a distinct shift of distribution curve to the right. A distinct asymmetric pattern of IMF location was confirmed with one-sample t-test (mean difference = .1243, CI, [0.0092, .2394], $P = .035$).

**NAC Asymmetry**

Breast morphograms demonstrating three types of anatomical NAC position encountered in patients analyzed is presented in Figure 5. In the majority of women (95.4%), the location of the right and left NAC was asymmetric (Figure 6). Similarly to the IMF, only 4.6% of patients ($n = 5$) had a symmetrical vertical position of the NAC. The most commonly observed NAC asymmetry was the right NAC located inferior to the left one (56.7%, $n = 59$), followed by left NAC located inferior to the right (38.7%, $n = 43$). The difference in vertical distance in the majority of patients varied within 2.0 cm. Analysis of the distribution of inter-nipple vertical distances is demonstrated in Figure 7. The distribution curve of the vertical

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<td>7.3 (8)</td>
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<td>$A_V$</td>
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Figure 2. Examples of patients with micromastia evaluated for augmentation mammoplasty with anatomical variants in inframammary fold (IMF) distribution (lower measurement line). (A) A 31-year-old woman with right IMF located below left IMF with interfoldal distance of 0.6 cm. (B) A 28-year-old woman with both IMF located on the same level with interfoldal distance of 0. (C) A 34-year-old woman with left IMF located below right IMF with interfoldal distance of 0.4 cm.
inter-nipple distance demonstrated a modest shift in favor of a right-lower position of the NAC.

**Breast Projection and Chest Wall Asymmetry**

Breast morphograms demonstrating different types of breast and chest wall projection encountered in the study cohort are demonstrated in Figure 8. The majority of women (97.2%, n = 108) had variation in the projection of their breasts in the anterior-posterior direction (Figure 9). Only two patients (2.8%) demonstrated equal projection of both breasts. The right breast had greater projection in 59 women (53.1%) compared to the left side, and the left breast was more projected in 44.1% of cases (n = 49). Differences in breast projection in most cases varied within 2.0 cm. A histogram illustrating the extent of asymmetry in breast projection is depicted in Figure 10. Typical morphograms measuring chest wall asymmetry in an anterior-posterior direction are demonstrated in Figure 8. Sixty-three patients (56.7%) had greater projection of the right chest wall, whereas 32 patients (28.8%) had greater projection of the left chest wall. Sixteen patients (14.5%) had symmetric chest wall projection.

**Factors Associated with IMF Asymmetry**

Breast parameters associated with IMF asymmetry included asymmetric NAC position and breast volume (Table 4). Asymmetrically located IMF demonstrated a strong positive correlation with asymmetry in both the NAC positions and breast volumes (r = .687, r = .461, respectively). Correlation of inter-fold and inter-nipple distances among patients with IMF asymmetry is shown in Figure 11. Patients with a lower right IMF most commonly had a lower ipsilateral NAC (49.1%), and less commonly a lower contralateral NAC (14.1%). Similarly, patients with a lower left IMF correspondingly had a lower ipsilateral NAC compared with the contralateral side (26.4%), and only a small proportion of these patients had a more inferiorly-located contralateral NAC (10.4%, Figure 12).

**DISCUSSION**

Evaluation and identification of pre-existing breast asymmetries is a critical part of the pretreatment evaluation of patients undergoing augmentation mammoplasty. Thorough breast dimensional analysis allows a surgeon to create a precise surgical plan, factoring in these asymmetries, in order to achieve an ideal aesthetic outcome. Detailed discussion between surgeon and patient about pre-existing breast asymmetries allows a greater sense of patient engagement in the surgical planning process, more understanding of normal anatomic variations, and a greater likelihood of appropriate expectations for their surgical outcomes.

Currently, there exists a large body of surgical literature dedicated to the evaluation of clinical morphology of the female breast. Asymmetry of various breast features has been systematically studied and documented in numerous clinical reports.11-19 The vast majority of existing studies, however, are focused on the analysis of breast volume, shape and anthropometric distances, whereas asymmetry in the IMF levels has been the focus of little attention.15

The IMF constitutes a stable anatomical structure that provides adherence between the dermal layer of the skin and the superficial fascia, providing structural support of
the mammary gland. For this reason, the IMF is an essential defining feature of female breast aesthetics, and a critical landmark in surgical planning. Particularly in the smaller-volume breast, where the IMF and lower pole structure are more likely to be evident, achieving symmetry of this fold is an important goal, in order to provide the most aesthetically desirable outcome. Augmentation mammoplasty techniques emphasize the importance of preservation of the existing symmetric IMF and correction of pre-existing asymmetry of the folds. Despite the critical role of the IMF in aesthetic breast surgery, the incidence and extent of IMF asymmetry in female breast has been poorly studied. Rohrich et al described the presence of asymmetry of IMF positions among women evaluated for breast augmentation. Analysis of patients’ clinical photographs by physician observers was performed with asymmetry documented in 30% of women. This study, however, lacks a detailed analysis of the relative positional anatomy of the IMF, thus limiting the clinical applicability of the results. Additionally, analysis of 2-dimensional photographs by clinical observers can lack accuracy and be associated with significant inter-observer measurement variations.

More recently, breast and chest wall asymmetries were evaluated using 3-D scanners and grating photogrammetry...
technology in women undergoing breast reduction where an asymmetric position of the IMF was found in 44% of patients.\textsuperscript{15} However, asymmetry was defined as a difference of .5 cm or greater, which may result in an underestimation of the true prevalence of asymmetry, compared with analyses using finer measurement to define smaller differences in fold height.

The key finding of the current study is that the majority of women with micromastia seeking augmentation mammoplasty demonstrated some degree of pre-existing asymmetry in their IMF positions. In 91\%, the vertical position of the IMF was within 1.0 cm of the contralateral side, and in 64.8\% of patients, variation was within .5 cm. Some authors have suggested that a difference in a patient’s IMF height of < .5 cm carries limited practical relevance, since it is not easily detected by the naked eye.\textsuperscript{15} While certainly true that lesser degrees of difference are likely of lesser significance, in our opinion, a precise attention to the determination of the IMF position on the chest wall remains important in aiming for the best possible aesthetic outcome. This is especially true in augmentation mammoplasty, where smaller volumes and the lifting effect of augmentation can tend to bring the IMF into greater visibility postoperatively, and magnify pre-existing breast asymmetry.\textsuperscript{4,5} Therefore,

Figure 8. Examples of patients with micromastia evaluated for augmentation mammoplasty with different type of breast and chest wall projection (red line). (A) A 37-year-old woman with greater projection of right breast. (B) A 32-year-old woman with greater projection of left breast. (C) A 28-year-old woman with equal projection of both breasts. (D) A 33-year-old woman with asymmetry of the chest wall (more projected right side). (E) A 31-year-old woman with asymmetry of the chest wall (more projected left side). (F) A 27-year-old woman with equal projection of the chest wall.
even minor differences between the breasts need to be appreciated and incorporated into the surgical plan, and the authors hope that an increased attention to the relative position of the IMF may help surgeons to obtain more predictable and favorable aesthetic outcomes.

Another key finding of this study is of the particular distribution of asymmetry. It might reasonably be expected that side-to-side asymmetries of variable degree might exist, but that they should be randomly distributed between right-lower and left-lower IMF, in a normal distribution centered on a mean difference of 0 cm. Instead, our findings demonstrate an apparent systematic rightward skew in the distribution of asymmetry: an “systematic asymmetry.” We demonstrate a statistically significant departure from the hypothesis of a symmetrical mean position, favoring greater prevalence of lower IMF position on the right. This finding is also consistent with observations made by our group in a separate cohort of macromastia patients (unpublished data).

We propose a classification of positional variation of the IMF into three types, ordered based on their observed prevalence (Figure 13): the majority of patients demonstrated more inferior location of both IMF and NAC on either right (49.1%) or left (26.4%) sides. Less commonly observed were anatomical variants where IMF was located more inferior on one side with ipsilateral NAC positioned more superior. NAC, nipple areola complex; IMF, inframammary fold.

Figure 13: Positional relationship between NAC and IMF and incidence of observed anatomical types. The majority of patients demonstrated more inferior location of both IMF and NAC on either right (49.1%) or left (26.4%) sides. Less commonly observed were anatomical variants where IMF was located more inferior on one side with ipsilateral NAC positioned more superior. NAC, nipple areola complex; IMF, inframammary fold.
developmental pathways. Alternately, deviations from programmed morphogenesis could arise secondary to external stimuli. Environmental causes such as, most notably, gravitational forces applied persistently to the fascioaponeurotic support system of the breast could possibly cause asymmetric attenuation of the IMF of patients, especially with non-equivalent breast volumes. The role of environmental causes in developing facial asymmetry is well-established. One potential functional external factor, hand dominance, is strongly asymmetrically-distributed in the general population, with an excess of right-handed individuals, and was not assessed in the current study. One could speculate that uneven patterns of use and muscular development based on hand dominance could result in the unequal development of bony or soft tissue structures on each side of the chest, resulting in an anatomical asymmetry. Although asymmetrical chest wall projection in this study did not correlate with IMF asymmetry, scoliosis has previously been shown to be associated with asymmetric female breast morphology. Symmetry of the chest wall in the current study was assessed with categorical variables, which limit interpretation of acquired data. Quantitative analysis of chest wall asymmetry and influence of scoliosis may warrant separate further assessment.

Another notable finding is the specific distribution pattern of a vertical NAC position in our study cohort. The most common type of NAC asymmetry observed was a right NAC located inferior to the left, followed by a left NAC inferior to the right. Only a small proportion of women had symmetrical NAC. Moreover, there was a strong correlation between positional variation of the IMF and the NAC in a vertical dimension, with a majority of patients found to have a lower position of the ipsilateral IMF and NAC. Correlation between the NAC and IMF positions, seen here in a micromastia cohort, may be unique to this patient population, and may not necessarily be observed in women with larger breasts, where ptosis may play a larger role. A woman’s NAC undergoes dynamic positional changes throughout morphogenesis, and tends to descend with normal aging, as glandular ptosis develops. Therefore, the positional relationship of the IMF and the NAC demonstrated in this patient population may vary with breast size and with degree of glandular ptosis, and may not necessarily be generalizable to other populations. Finally, breast volume demonstrated a positive correlation with IMF position, where larger breast volume correlated to

![Figure 13. Classification of IMF position. IMF, inframammary fold.](https://academic.oup.com/asj/article-abstract/36/2/156/2589279/download)
more inferior position of a patient’s ipsilateral IMF. This was also observed in the comparison of breast volume and NAC location. In our opinion, all three of these parameters (breast volume, IMF location, and NAC location) are part of a complex and inter-related structural system present within the female breast, where disproportion in one parameter can cause morphologic changes in the others. Therefore, asymmetries in a given patient’s breast volume, NAC or IMF position needs to be viewed as part of a distinct ensemble of interconnected parameters, and surgical alteration of one element can lead to changes in other components of this system. Given that postoperative breast asymmetry is a frequent cause of revision surgery with breast augmentation, data from this study may have important clinical implications with respect to optimizing symmetry. Equally important, these findings also provide a sound basis for a critical pretreatment discussion with patients seeking breast augmentation that the majority of women demonstrate significant asymmetries in pretreatment. Asymmetry in any breast parameter warrants a detailed pretreatment discussion with particular attention to breast volume, NAC location, and IMF position. The proposed classification of different types of IMF position, alone and in association with NAC location, can further assist in better understanding of each patient’s individual breast anatomy.

This study has certain limitations bearing discussion. All breast measurements were performed in women with micromastia seeking breast augmentation. Patients in this population typically present with distinct morphologic features of the breast, small volume with minimal or no glandular ptosis. Therefore, anthropometric data determined here may not be generalizable to other populations, and separate assessment of other specific populations would likely be informative. Women with larger breast volume and a more significant degree of mammary ptosis are expected to likely exhibit different patterns of asymmetry of breast features. Thus, analysis of IMF asymmetry in other categories of women warrant separate studies. An additional possible element of variation not assessed here is the position of the IMF in the horizontal axis. The IMF is a complex anatomical structure and demonstrates structural variations not only in a vertical position on the chest wall, but also in the individual horizontal length, and the distance between medial boundaries (horizontal interfold distance). It has been shown previously that medial, central, and lateral aspects of each IMF are located on different levels of the chest wall. Furthermore, central and lateral portions of each IMF undergo more prominent caudal descent over time, whereas the medial part of the fold remains more fixed on the chest. This phenomenon and its clinical relevance warrant separate detailed evaluation using 3D imaging technology. Moreover, natural changes in the IMF position with aging, as well as the influence of mammary augmentation on the location of IMF require further investigation.

That systematic asymmetry in IMF position should have apparently escaped notice before now suggests that favorable results may be achievable in the face of IMF asymmetry. Without a doubt, asymmetry of breast volume must be considered a more important parameter to consider than IMF asymmetry in surgical planning of augmentation mammoplasty. Nonetheless, the present results support the view that IMF position is an important, even though not the single most important, characteristic of female breast aesthetics.

Finally, many readers may wish to see an evaluation of anatomic parameters both before and after augmentation mammoplasty; the current study limits itself to a one-time point data collection (breast imaging during pretreatment consultation) and does not provide follow-up examination of breast asymmetry after surgery. Evaluation of asymmetry in breast characteristics before and after augmentation is clearly very relevant to clinical practice. However, the authors wish to draw attention to the subject of pre-existing asymmetry, since it describes an underlying anatomic variance. Especially given a systematic rightward skew, this stands contrary to general expectations among surgeons, and is not previously reported. Postoperative asymmetry likely relates more clearly to surgical technique, and is likely to vary somewhat according to the individual surgeon. The topic is, nonetheless, a focus of separate ongoing follow-up studies by our group.

Despite its limitations, the present study provides novel information about existing patterns of positional anatomy of the IMF alone and in correlation with NAC location in women with micromastia seeking mammary augmentation. To the best of our knowledge, this study represents the first realization of a detailed quantitative assessment of IMF asymmetry in women undergoing breast augmentation. The 3D imaging software is much more accurate than physician-made measurements, as the digital analysis of IMF asymmetry allows for the detection of differences in vertical IMF position as small as 1.2 mm. These results are consistent with multiple breast anthropometric reports, which have reported that natural symmetry between a woman’s breast features is rare and absolute symmetry is unlikely to exist.

CONCLUSION

The majority of women presenting for augmentation mammoplasty demonstrate significant asymmetry of their IMF locations, NAC locations, and breast projection, with an asymmetric distribution revealing an excess of right-lower positioning of both the IMF and the NAC, compared to expectations based on random variation. We propose a classification system based on the observed IMF positions and the relationship between the IMF and NAC locations. This information can further assist clinicians in better understanding...
their patients’ anatomy in order to achieve more predictable and aesthetically optimal postoperative results.

**Disclosures**

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**REFERENCES**