Original Article

Quantitative assessment of inframammary fold in Asians: an MRI study

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Background: The inframammary fold (IMF) is a critical structure affecting the aesthetics of the breast, yet the anatomy and location of the IMF remain controversial. The purpose of this study was to quantitatively evaluate the thickness and location of IMF utilizing magnetic resonance imaging (MRI).

Methods: The MRI images of 240 breasts from 120 Asian women were analyzed. The quantitative measurements consisted of breast width, breast projection, nipple to inframammary fold, breast volume, IMF tissue thickness, and IMF position. The IMF position was evaluated by referring to the ribs, as well as measuring the distance between IMF and the inferior of the fifth rib.

Results: The mean values of central thickness, medial thickness, and lateral thickness were 1.50±0.59, 1.46±0.60, and 1.76±1.04 cm, respectively. IMF central thickness demonstrated a moderate positive correlation with breast projection (r=0.559, P<0.001) and breast volume (r=0.523, P<0.001). The proportions of IMF located at the fourth intercostal, the fifth rib, the fifth intercostal, the sixth rib and the sixth intercostal were 5.8%, 29.2%, 43.3%, 20.4% and 1.3%, respectively. The average distance between IMF and the inferior of the fifth rib was 0.69±1.40 cm. 60.0% of women had near-symmetrical IMF, while 17.5% had left higher IMF and 22.5% had right higher IMF.

Conclusions: This study used MRI to quantitatively assess the anatomy of IMF. The detailed knowledge of IMF would facilitate the ideal aesthetic outcome of mammaplasty.

Keywords: Inframammary fold (IMF); anatomy; magnetic resonance imaging (MRI); mammaplasty

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Introduction

The inframammary fold (IMF), one of most critical visual landmarks for the breast, significantly influences the results of mammaplasty, including breast augmentation, reduction and reconstruction. The IMF serves as the inferior border of the breast, providing structural support for subpectoral implant and preventing its migration (1). This is also the marker to define the severity of breast ptosis (2). The symmetry of the IMF position correlates closely with breast aesthetics (3). Therefore, it is essential to understand the anatomy and location of the IMF for mammaplasty.

The IMF is composed of a crest of dense nodular tissue, forming an adhesion area between the dermal layer of the skin and the underlying chest wall. However, there remains controversy in the literature regarding the

anatomical structure and location of the IMF. Early studies identified the IMF as a ligamentous structure, while other studies could not reaffirm the ligament's structure but found a dense collagen network in this region (4-6). The ribs and pectoralis major muscle were frequently used as the reference for positioning IMF. Nevertheless, it is still debated about which rib the IMF is located on, and the relationship between the IMF and the inferior origin of the pectoralis major muscle (4,6-8).

The IMF could be quite heterogeneous among breasts, therefore studies including large samples of IMFs are required (3,9). Although cadaveric studies can reveal the detailed anatomy of the IMF, the disadvantages are the high cost and the lack of precise quantitative measurements (4,7). Quantitative studies of IMF have been performed using medical imaging techniques, such as magnetic resonance imaging (MRI), computed tomography (CT), and three-dimensional (3D) surface imaging (10-12). Particularly, MRI is superior in soft tissue imaging, with the 3D reconstruction technique allowing precise positioning and quantitative measurement of the IMF.

Therefore, the purpose of present study was to quantitatively evaluate the thickness and location of IMF in Asians using MRI images. This study also sought to identify body and breast parameters associated with the thickness and location of IMF respectively. Furthermore, the study intended to assess the incidence of asymmetry of IMF location in Asian women. We present this article in accordance with the STROBE reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-23-65/rc).

Highlight box

Key findings

- This study was to quantitatively evaluate the thickness and location of inframammary fold (IMF) utilizing magnetic resonance imaging.

What is known and what is new?

- The majority of IMFs were thicker than 1 cm, with an average thickness of 1.50±0.59 cm in the central IMF.
- The most common location of IMF was the fifth intercostal space, followed by the fifth and sixth ribs. Particularly, 40% of Asian women had asymmetrical IMFs, which needs to be taken into consideration before surgery.

What is the implication, and what should change now?

- The detailed findings of the IMF provide plastic surgeons with a valuable reference for achieving the desired aesthetic outcome of mammaplasty.

Methods

Patients

The MRI images of 240 breasts from 120 Asian women obtained between January 2015 and January 2020 were included in this study retrospectively. The main indication for the patients to undergo MRI was the detection of breast lesions. The inclusion criterion was full visualization of breast without obvious abnormalities. The exclusion criteria were previous breast surgery, radiotherapy, and Poland syndrome. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Ethical Committee of Tongji Hospital (No. IRB20220468). Written informed consent was waived by ethical committee as this study was retrospective and non-invasive.

MRI technique

Breast MRI images were acquired by a 3.0T scanner (Skyra, Siemens Healthcare, Erlangen, Germany) using a dedicated 16-channel phased-array breast coil. Patients were scanned in the prone position. T1 fat-saturated images were analyzed in this study using a transverse three-dimensional T1-weighted (t1_fl3d_tra) sequence: repetition time 7.35 ms, echo time 3.81 ms, slice thickness 1.0 mm, FOV 340×340 mm^2, flip angle 10°.

Anthropometric measurements of breast

The quantitative measurements of breast consisted of breast width, breast projection, nipple to inframammary fold (NIMF), and breast volume. Breast width was the distance between the medial and lateral termination of the breast in the axial central view (*Figure 1A*). Breast projection was the distance between the nipple and chest wall in the axial central view (*Figure 1A*). NIMF was the surface distance between the nipple and IMF in the sagittal central view (*Figure 1B*). Breast volume was calculated by converging all areas of breast prominence on MRI images (*Figure 1C*). The measurements were carried out with OsiriX 9.0 software (Pixmeo SARL, Geneva, Switzerland).

Anthropometric measurements of IMF

The quantitative assessment of IMF consisted of IMF tissue thickness and IMF position. The IMF tissue thickness was measured in the three sagittal views, including

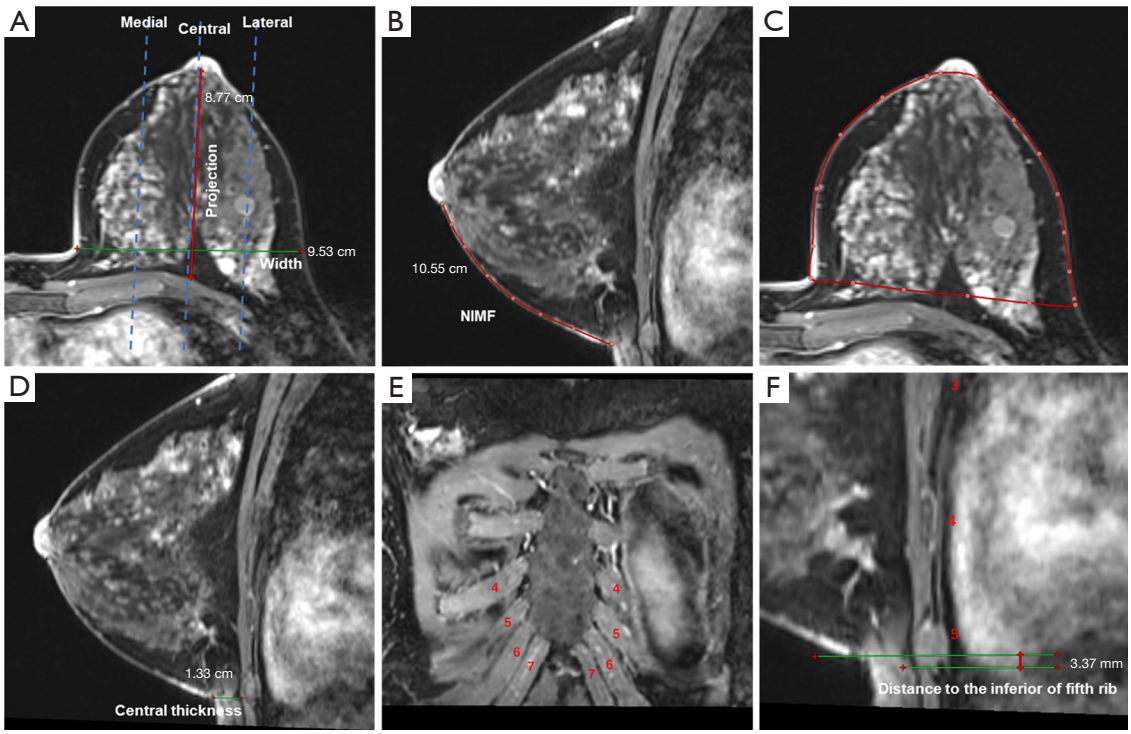

Figure 1 Anthropometric measurements of breast and IMF in resonance magnetic imaging. (A) Axial view with measurements of breast width and projection. (B) Sagittal view with measurement of NIMF. (C) Measurement of breast volume. (D) Measurement of central thickness of IMF. (E) Coronal view for locating the ribs. (F) Measurement of the distance between IMF and the inferior of fifth rib. IMF, inframammary fold; NIMF, nipple to inframammary fold.

central thickness, medial thickness, and lateral thickness (*Figure 1D*). Additionally, the IMF position was evaluated with reference to ribs. The order of the ribs was determined in the coronal view (*Figure 1E*). After the fifth rib was marked, the image was converted to the sagittal central view with the position of the fifth rib identified (*Figure 1F*). Besides, the distance between IMF and the inferior of the fifth rib was measured (*Figure 1F*).

Statistical analysis

The measured values were presented as mean ± standard deviation (SD). The paired *t*-test was used to compare the measurements of the left and right breasts. The relationships among body, breast, and IMF measurements were evaluated using the Pearson correlation coefficient. The chi-square test was used to determine the difference in IMF position between the left and right breasts. P<0.05 was considered to be a statistically significant difference. The data were analyzed using SPSS 19.0 statistical software (SPSS Inc., Chicago, IL, USA).

Results

A total of 120 Asian women with 240 breasts were included. The mean age of the women was 41.41±9.94 years. The average body mass index (BMI) was 23.83±2.64 kg/m^2 with an average height of 1.63±0.05 m and an average weight of 63.24±7.64 kg.

Breast anthropometrics

The anthropometric measurements of breasts are listed in Table S1. The mean values of breast width, breast projection, and NIMF were 8.60±1.57, 7.31±2.21, and 9.12±1.71 cm, respectively. There was no statistical difference between the right and left breasts in these breast measurements (P>0.05). The average breast volume was 371.90±188.70 mL, and there was no significant difference between bilateral breasts (P>0.05).

Table 1 Anthropometric measurements of inframammary fold

Breast parameter	Breast (mean ± SD)			P
	Total	Left	Right	
Breast width (cm)	8.60±1.57	8.65±1.60	8.56±1.55	0.656
Breast projection (cm)	7.31±2.21	7.21±2.21	7.40±2.22	0.517
NIMF (cm)	9.12±1.71	9.29±1.65	8.96±1.76	0.136
Breast volume (mL)	371.90±188.70	366.76±182.02	376.97±195.88	0.676

SD, standard deviation; NIMF, nipple to inframammary fold.

Table 2 Correlation of body, breast and inframammary fold measurements

Parameter	Central thickness		Medial thickness		Lateral thickness		Distance to the inferior of fifth rib	
	Pearson	P	Pearson	P	Pearson	P	Pearson	P
Age	0.163	0.012	0.181	0.005	0.162	0.012	0.096	0.138
Weight	0.227	<0.001	0.125	0.054	0.090	0.166	–0.058	0.374
Height	0.117	0.071	0.076	0.244	0.065	0.315	–0.068	0.296
BMI	0.186	0.004	0.091	0.159	0.060	0.354	–0.025	0.706
Breast width	0.320	<0.001	0.253	<0.001	0.207	0.001	0.218	0.001
Breast projection	0.559	<0.001	0.426	<0.001	0.221	0.001	–0.069	0.285
NIMF	0.319	<0.001	0.264	<0.001	0.183	0.005	0.183	0.004
Breast volume	0.523	<0.001	0.420	<0.001	0.256	<0.001	0.041	0.528

BMI, body mass index; NIMF, nipple to inframammary fold.

IMF thickness

The measurements of IMF thickness are listed in *Table 1*. The mean values of central thickness, medial thickness, and lateral thickness were 1.50±0.59 cm, 1.46±0.60 cm, and 1.76±1.04 cm, respectively. Only 43 (17.9%) breasts had the central thickness of IMF less than 1.0 cm. There was no statistical difference between the left and right breasts in IMF thickness (P>0.05). The correlation between IMF thickness and body or breast measurements is shown in *Table 2*. IMF central thickness demonstrated a moderate positive correlation with breast projection (r=0.559, P<0.001) and breast volume (r=0.523, P<0.001). Similarly, there was a moderate positive correlation between IMF medial thickness and breast projection (r=0.426, P<0.001) or breast volume (r=0.420, P<0.001). IMF central thickness showed a weak positive correlation with body weight (r=0.227, P<0.001), or BMI (r=0.186, P=0.004). The correlation between IMF thickness and the other measurements was weak or irrelevant.

IMF location

The IMF location was classified as fourth intercostal, fifth rib, fifth intercostal, sixth rib, or sixth intercostal (*Table 3*). The numbers of IMFs located at the fourth intercostal, the fifth rib, the fifth intercostal, the sixth rib, and the sixth intercostal were 14 (5.8%), 70 (29.2%), 104 (43.3%), 49 (20.4%) and 3 (1.3%), respectively. The chi-square test showed no significant difference in the IMF location between the left and right breasts (P=0.735). The average distance between IMF and the inferior of the fifth rib was 0.69±1.40 cm (*Table 1*), and the paired *t*-test showed no significant difference between bilateral breasts (P>0.05). There was a weak or no correlation between the distance to the inferior of the fifth rib and body or breast measurements (*Table 2*).

IMF asymmetry

IMF symmetry can be divided into three types with

Table 3 Location of inframammary fold with reference to ribs

Parameter	Central thickness		Medial thickness		Lateral thickness		Distance to the inferior of fifth rib	
	Pearson	P	Pearson	P	Pearson	P	Pearson	P
Age	0.163	0.012	0.181	0.005	0.162	0.012	0.096	0.138
Weight	0.227	<0.001	0.125	0.054	0.090	0.166	–0.058	0.374
Height	0.117	0.071	0.076	0.244	0.065	0.315	–0.068	0.296
BMI	0.186	0.004	0.091	0.159	0.060	0.354	–0.025	0.706
Breast width	0.320	<0.001	0.253	<0.001	0.207	0.001	0.218	0.001
Breast projection	0.559	<0.001	0.426	<0.001	0.221	0.001	–0.069	0.285
NIMF	0.319	<0.001	0.264	<0.001	0.183	0.005	0.183	0.004
Breast volume	0.523	<0.001	0.420	<0.001	0.256	<0.001	0.041	0.528

BMI, body mass index. NIMF, nipple to inframammary fold.

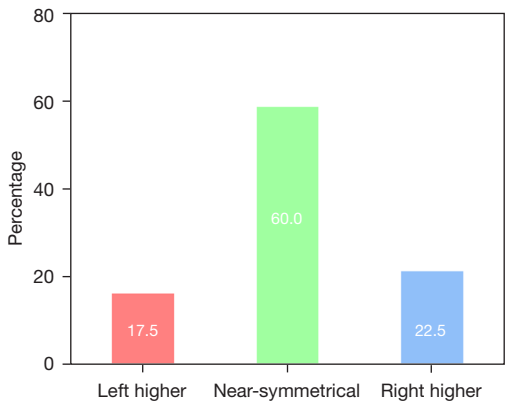

Figure 2 Asymmetry of IMF position with reference to ribs. Bilateral IMFs located in the same rib or intercostal space are considered near-symmetrical. IMF, inframammary fold.

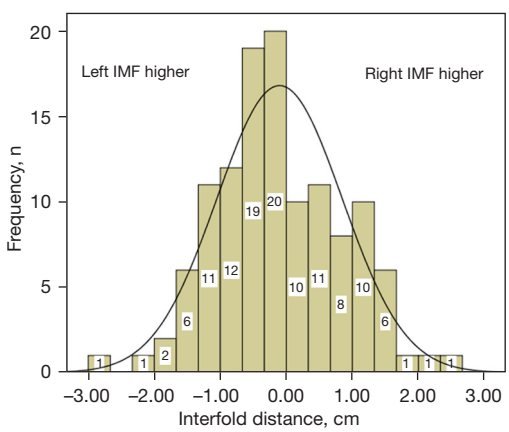

Figure 3 Distribution of the distance between bilateral IMF. IMF, inframammary fold.

reference to ribs (*Figure 2*). The majority of women (60.0%, n=72) had near-symmetrical IMF positions as bilateral IMFs located in the same rib or intercostal space. 17.5% of women (n=21) had left IMF higher than right IMF, while 22.5% of women (n=27) had right IMF higher. The interfold distance was calculated by measuring the distance between bilateral IMFs and the inferior of the fifth rib, and the variation in interfold distance is shown in *Figure 3*. Similarly, 21 women (17.5%) had left higher IMF with interfold distance less than –1.0 cm, and 19 women (15.8%) had right higher IMF with interfold distance more than 1.0 cm.

Discussion

Mastectomy is an essential treatment for most patients with breast cancer. As well as oncological treatment, the aesthetics of the breast is receiving increasing attention. Skin-sparing mastectomy is possible to preserve appropriate skin and tissue for breast reconstruction. Specifically, it is important to preserve the IMF structure during mastectomy, which would considerably facilitate breast reconstruction and lead to a more pleasing aesthetic result (13,14). Unfortunately, the supporting structures of IMF will be destroyed due to an extensive subcutaneous dissection to remove the glandular and fat tissue of IMF. Therefore, IMF reconstruction is the critical step in breast reconstruction to achieve satisfactory results. Preoperative assessment and intraoperative control of the IMF are also important in breast augmentation. The position of the IMF needs to be adjusted accordingly due

to the implantation of breast prosthesis or preoperative asymmetry of the IMFs. As a result of the failure of the IMF management, several postoperative complications would appear, such as double-bubble, implant descent, and visible scar (15,16). Additionally, breast reduction removes the inferior glandular and skin tissue of macromastia, thus requiring IMF elevation and reconstruction. Importantly, IMF reconstruction or redefinition relies on a thorough understanding of its anatomy and location.

In a cadaveric study, Maillard *et al.* identified a crescent-shaped ligamentous band making a strong resistance to retropectoral dissection (17). Similarly, Bayati *et al.* reported that a ligamentous structure of the IMF arose from the periosteum of the fifth rib and the intercostal fascia between the fifth and sixth ribs (4). However, Garnier *et al.* suggested no ligament-like structure in the IMF by histological examination (18). Furthermore, Boutros *et al.* proposed that the increased dermal collagen fibers were the main reason for the formation of the IMF (5). Rehnke *et al.* identified a 3D fibrofatty fascial system associated with the formation of the IMF, where the fascial ring around the breast was anchored to the chest wall (19). Recently, Takaya *et al.* found that the fascia below the dermis gradually fused posteriorly and upward to join the deep fascia of the pectoralis major muscle in the IMF region (20). Overall, the IMF acts as an adhesion zone between the dermis and the pectoralis fascia, although it remains controversial whether the structure of the IMF is ligamentous or dense collagen network.

The thickness of IMF reflects the amount of tissue, which is of clinical significance for mammaplasty. The knowledge of IMF thickness can guide glandular resection to preserve a desirable amount of subcutaneous tissue for skin-sparing mastectomy (10). Besides, the tissue coverage on the prosthesis for breast augmentation can be assessed by reference to the IMF thickness. Also, the thickness of IMF can provide guidance for breast reduction, as the reconstructed IMF should be thinned to a normal IMF thickness (21). In this study, the mean thickness in the central aspect of IMF was measured as 1.50±0.59 cm. Of these, 17.9% of breasts had an IMF thickness of less than 1.0 cm. In addition, we found that the IMF thickness was positively correlated with breast projection and breast volume. However, a study of Brazilian women measured a larger IMF thickness of 2.40 cm than our data (10). This may be due to ethnic differences, as previous research has shown that Brazilian women have larger breast sizes than Asian women (22).

Accurate positioning of the IMF is crucial for mammaplasty. As shown in previous studies, the rib is a convenient anatomical landmark for locating the IMF. However, it is unclear which rib is most relevant to the IMF. Handel *et al.* proposed that the IMF extended a semicircle from the sternum to the midaxillary line over the second to sixth ribs (23). Bayati *et al.* identified the IMF derived along the periosteum of the fifth and sixth rib (4). Muntan *et al.* reported that the IMF was located between the sixth and seventh ribs in the midclavicular line (6), while Takaya *et al.* observed the fascia from the dermis joined the deep fascia at the fourth and fifth rib (20). Most previous studies were based on cadaver dissection, which was difficult to identify IMF position due to the muscles overlapping and attaching to the ribs. A recent study used chest CT to locate IMF and confirmed that the IMF was located nearest to the sixth rib (11). Differently, we found that the IMF was most frequently located at the fifth intercostal space with a mean distance of 0.69±1.40 cm between IMF and the inferior of the fifth rib. Additionally, IMF position was revealed to be independent of body or breast parameters, which is similar to the finding of the CT study (11).

The asymmetry of IMF affects the aesthetics of the breasts, which should be taken more attention before mammoplasty. Yeslev *et al.* reported that the majority of Caucasian women with micromastia suffered the asymmetry of IMF by 3D imaging analysis (12). Similarly, 44% of the Asians undergoing breast augmentation were regarded as IMF asymmetrical under the assessment of the 3D scanner (24). This study also revealed that nearly 40% of Asian women had asymmetric IMFs by using MRI to locate the IMF. As mammaplasty may magnify preoperative differences in the breasts, even small differences need to be taken into account to plan the procedure accordingly. Therefore, identification of pre-existing IMF asymmetry is necessary to achieve an ideal aesthetic result. To correct the asymmetry of IMF, the IMF needs to be refixed in the proper position to achieve symmetry and definition.

There are some limitations to this study. Firstly, this study included only Asian women, thus studies with larger samples of other races are warranted to investigate the effect of racial differences on IMF. Secondly, MRI examination should be in the prone position, the change to supine or standing position may affect the location of the IMF. Compared to the standing position, the IMF may be slightly elevated in the prone position due to gravity. Additionally, we have only measured the IMF position in the central aspect, while the IMF exhibits an arc-shaped structure with different positions on the medial, central, and lateral of each IMF.

Conclusions

The present study achieved the quantitative assessment of IMF using MRI images in a larger Asian sample. The majority of IMFs were thicker than 1 cm, with an average thickness of 1.50±0.59 cm in the central IMF. The most common location of IMF was the fifth intercostal space, followed by the fifth and sixth ribs. Particularly, 40% of Asian women had asymmetrical IMFs, which needs to be taken into consideration before surgery. The detailed findings of the IMF provide plastic surgeons with a valuable reference for achieving the desired aesthetic outcome of mammaplasty.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://gs.amegroups.com/article/view/10.21037/gs-23-65/rc

Data Sharing Statement: Available at https://gs.amegroups.com/article/view/10.21037/gs-23-65/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-23-65/coif). The 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). The study was approved by the Ethical Committee of Tongji Hospital (No. IRB20220468). Written informed consent was waived by ethical committee as this study was retrospective and non-invasive.

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