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ARTICLE

Thorax anthropometric position index: a simple evaluation of the inframammary fold position in the thorax

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ABSTRACT

Appropriate positioning of the inframammary fold (IMF) is essential for breast reconstruction. The purpose of this study was to quantitatively measure and evaluate the anthropometric position of the IMF in the thorax. A total of 145 Japanese women with unilateral breast cancer were analyzed. To indicate the superior-inferior position of the IMF on the non-diseased side, the distances from the sternal notch (SN) to the IMF along the midline (SN–IMFM) and from the SN to the umbilicus (UB) (SN–UB) were measured. A new index, the thorax anthropometric position (TAP) index for the IMF, was then defined as the ratio of SN–IMFM to SN–UB. The TAP index was calculated for each patient, and its correlations with demographic parameters, including age, body height, and body mass index, were statistically assessed. The TAP index was normally distributed and ranged from 0.500 to 0.704, with a mean of 0.590. Multivariate analysis revealed that age was an independent factor associated with a higher TAP index ($p < .01$). In addition, the paired *t*-test showed that the TAP index was significantly greater in the standing position than in the supine position ($p < .001$). The position of the IMF in the thorax could be objectively described by the TAP index, and it was suggested to become inferior with age and the standing position. The index, along with these findings, will provide useful information for the evaluation of the breast contour in an objective and simple manner.

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Introduction

The shape and position of the inframammary fold (IMF) significantly influence the contour of the breast [1–3]. In breast reconstructive surgery, positioning the IMF in an appropriate position is a crucial step for obtaining an aesthetically pleasing result. It is important to create a breast that is similar to the contralateral breast and to achieve symmetry between the right and left sides; therefore, the aesthetic results of breast reconstruction are often evaluated based on the symmetry of the vertical position of the IMF [4,5]. Recently, a growing number of women diagnosed with hereditary breast and ovarian cancer syndrome (HBOC) choose to undergo bilateral risk-reducing mastectomy and reconstruction [6,7]. However, judging the results of bilateral breast reconstruction is difficult because the original IMF structures are lost or destroyed on both sides. Therefore, the search for an ideal IMF height and a standard protocol for measuring the breast is becoming an increasingly important task.

Although previous studies have examined the position of the IMF by measuring the distance between the IMF and the ribs or pectoralis major muscle [8–11], these results remain controversial. In addition, most of these data are obtained from cadaver dissection, surgical field, or imaging analysis in the supine position; thus, information on body surface of living patients in a standing position remains scarce [12].

Here we aimed to quantitatively determine the height of the IMF in the thoracic region using a simple anthropometric measurement of patients with unilateral breast cancer. Furthermore, statistical analyses were performed to elucidate whether the patients' body position (standing or supine) and demographic parameters affect the height of the IMF.

Materials and methods

Ethical approval for this study was obtained from the ethical review board, which granted an informed consent waiver because the study was retrospective and not interventional. Data of 153 consecutive Japanese women with unilateral breast cancer who underwent mastectomy and simultaneous expander or implant reconstruction at a single center between December 2015 and November 2018 were reviewed in this study. Collected clinical data included age, height, and body mass index (BMI). Eight patients with bilateral breast cancer or with insufficient clinical data were excluded from this study.

Preoperative measurements based on anatomical landmarks were performed as follows: first, the most inferior point of the IMF of the non-diseased side on the midline (IMFM) was marked in a standing position. Then, the distance between the sternal notch (SN) and superior border of umbilicus (UB) (SN–UB), and the distance between the SN and IMFM (SN–IMFM) were measured. SN–UB and SN–IMFM were similarly measured in the supine position.

The ratio of SN–IMFM to SN–UB was calculated to evaluate the relative height of IMF in the thoracic region and was defined as the thorax anthropometric position (TAP) index of the IMF (Figure 1). The TAP index was also calculated in the supine position. A greater TAP index indicates a more inferior IMF position.

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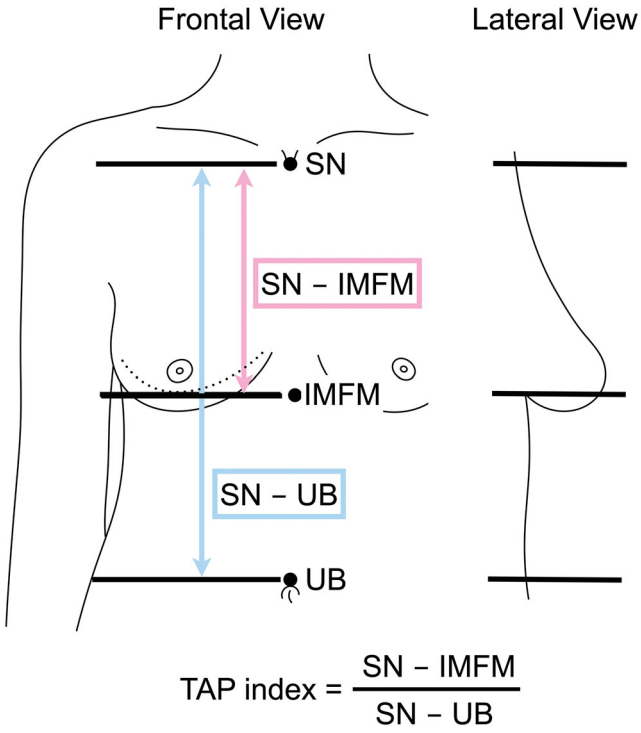

Figure 1. Anatomical landmarks for calculating the TAP index. TAP index: thorax anthropometric position index; IMFM: the position of the IMF on the midline; SN: sternal notch; UB: umbilicus.

Data collected were organized using Microsoft Excel for Mac 2016 (Microsoft Corp., Redmond, WA), and all statistical analyses were performed with EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria) [13]. The TAP index was compared based on age (younger than 50 years versus 50 years older), height (<160 cm versus ≥160 cm), BMI (<22.5 kg/m^2 versus ≥22.5 kg/m^2), and the measured side (right versus left) using Student's *t*-tests. Multivariate regression analysis was also performed to elucidate independent factors associated with the TAP index. Pearson's correlation coefficients were calculated to assess the relationship between the TAP index and age. Furthermore, the TAP index in the standing or supine position of the same patients was compared using paired *t*-test. Statistical significance was set at $p < .05$.

Results

A total of 145 patients (145 breasts) were included in this study. Forty-five percent of patients ($n = 65$) patients had right sided breast cancer. The demographic characteristics of the patients and the results of the anthropometric measurement are shown in Table 1. There was no apparent left–right asymmetry in the breasts.

The TAP index ranged from 0.500 to 0.704 (mean ± standard deviation, 0.590 ± 0.038). The Shapiro-Wilk test showed that the TAP index was normally distributed ($p = .13$). Univariate analysis showed significant differences in the TAP index regarding age and body height, while there was no significant difference in BMI and the measured side (Table 2). Multivariate regression analysis revealed that age was the only independent parameter which significantly correlates with higher TAP index (Table 3). Consistent with these results, age and the TAP index showed a relatively weak but significant positive correlation ($R = 0.313$, $p < .001$, Figure 2). Paired *t*-test showed that the TAP index in the standing position was significantly greater than that in the supine position (0.590 ± 0.038 versus 0.578 ± 0.036; $p < .001$).

Representative cases of a younger and an older patient with similar height and BMI are compared in Figure 3. Consistent with the above results, the IMF of the younger patient was higher than that of the older patient in the thoracic region.

Table 1. Demographic characteristics and anthropometric measurements of patients.

Parameter	Mean ± Standard Deviation (range)
Age, years	48.2 ± 8.8 (23–72)
Body height, cm	157.9 ± 5.5 (145.0–171.6)
BMI, kg/m^2	22.4 ± 4.3 (15.7–43.5)
SN–IMFM, cm	22.3 ± 1.9 (17.0–29.0)
SN–UB, cm	37.8 ± 2.8 (32.0–50.5)

BMI: Body mass index; SN–IMFM: the distance between the sternal notch (SN) and the inframammary fold on the midline (IMFM) in a standing position; SN–UB: the distance between SN and the umbilicus (UB) in a standing position.

Table 2. Univariate analyses of TAP index-associated factors.

Parameter	TAP index*	*p*
Age		
<50 years	0.582 ± 0.034	.002**
≥50 years	0.603 ± 0.041	
Body height		
<160 cm	0.595 ± 0.040	.048**
≥160 cm	0.582 ± 0.034	
BMI (kg/m^2)		
<22.5 kg/m^2	0.587 ± 0.035	.147
≥22.5 kg/m^2	0.596 ± 0.043	
Side		
Right	0.587 ± 0.038	.489
Left	0.592 ± 0.038	

TAP index: thorax anthropometric position index; BMI: body mass index.
*Data are expressed as mean ± standard deviation. **Statistically significant.

Table 3. Multivariate analyses of TAP index-associated factors.

Parameter	*p*	PRC	95% CI
Age			
<50 years	*		
≥ 50 years	.006**	0.018	0.005 – 0.031
Body height			
<160 cm	*		
≥160 cm	.141	–0.009	–0.022 to 0.003
BMI (kg/m^2)			
<22.5 kg/m^2	*		
≥22.5 kg/m^2	.357	0.006	–0.007 to 0.019
Side			
Right	*		
Left	.675	–0.003	–0.015 to 0.010

TAP index: thorax anthropometric position index; BMI: body mass index; PRC: partial regression coefficient; CI: confidence interval.
*Set as controls. **Statistically significant.

Discussion

The IMF visually determines the position, shape, and ptosis of the breast. Despite its aesthetic importance, the anthropometric position of the IMF in the thoracic region is rarely discussed [12]. In this study, we defined a new index, thorax anthropometric position (TAP) index of the IMF which represents the ratio of the distance between the sternal notch and the IMF to the distance between the sternal notch and the umbilicus. The TAP index enabled us to describe the position of the IMF objectively and

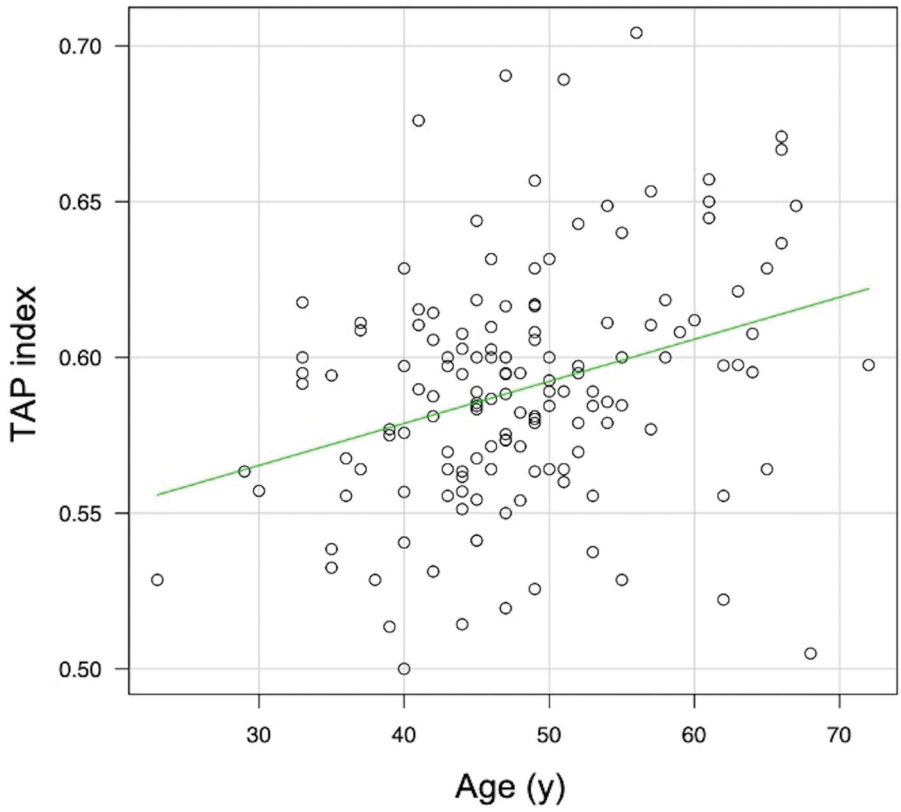

Figure 2. A scatter plot showing positive correlation between age and the TAP index TAP index, thorax anthropometric position index.

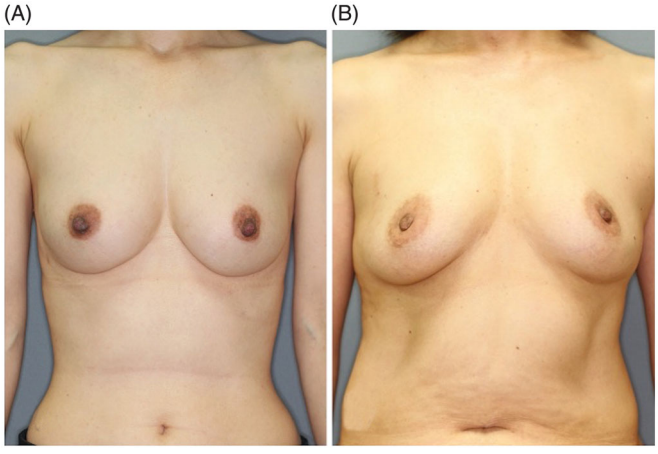

Figure 3. Representative cases of a younger patient and an older patient A, A 44-year-old patient with left-sided breast cancer (TAP index, 0.603; height, 160 cm; BMI, 19.5 kg/m^2) B, A 57-year-old patient with left-sided breast cancer (TAP index, 0.653; height, 161 cm; BMI, 20.0 kg/m^2) TAP index, thorax anthropometric position index; BMI, body mass index.

identify that the height of IMF becomes lower with age and in the standing position.

Previous studies have discussed the position of the IMF relative to the pectoralis major muscle, pectoralis minor muscle, and the ribs [8–11]. However, the details are still conflicting. For example, Nanigian et al. [8] reported that the IMF was located consistently inferior to the inferior origin of the pectoralis major muscle, while Baek et al. [10] argued that 66.7% of chests had the pectoralis major muscle above the IMF. In addition, because all these analyses were carried out using cadavers, surgical field, or CT/MRI imaging in the supine position, the most inferior point of the IMF cannot be precisely decided on the living body surface in a standing position. We therefore simply measured the position of IMF in a standing position relative to the body surface landmarks, the sternal notch and the umbilicus. The mean TAP index was 0.590, the reciprocal of which is close to the golden ratio, $\varphi = 1.61803$. Just as the golden ratio is sometimes observed in many life forms and phenomena, including humans [14], the average TAP index may represent an aesthetically pleasing proportion of the IMF in the thoracic region.

Direct anthropometric measurement of the breast has been very familiar to plastic surgeons in daily clinical practice and many studies on this theme can be found [4,12,15–19]. However, to the best of our knowledge, there is only one report which mentions both the distance between the sternal notch and the IMF (SN–IMFM) and the distance between the sternal notch and the umbilicus (SN–UB) [20]. Westreich [20] analyzed 50 Caucasian women aged 17–38 years with "aesthetically perfect breasts" and showed all results of SN–IMFM and SN–UB. The TAP index of this population would be 0.575, which is similar to but slightly smaller than our results. This discrepancy may be partly attributable to the different ethnicity, age distribution, and the unclear aesthetic selection criteria of the breast's form in this cohort.

The TAP index in our study was significantly greater in the older population than in the younger population and also in the standing position than in the supine position, which means that the height of IMF reduces with age and in the standing position. Considering that the age of the population in Westreich's [20] study was younger than in our study, it is reasonable that the TAP index in their study was greater than in our study. The histological structure of the breast may account for the relationship between the IMF and age, and the IMF and body position. Although it remains a controversial topic, it is proposed that the corpus mammae in the breast is surrounded and attached to the

chest wall by the superficial fascia system, and the IMF is the inferior border of this system [1,2,21–23]. In addition, the superficial structures that constitute the breast deteriorates with age; ligaments are more lax and less dense in older women [22]. It can be deduced from the above description that aging and gravitational force lowers the breast along the chest wall, resulting in the lowered IMF position.

Two major limitations of this study should be noted. First, it included only Japanese women with unilateral breast cancers; an investigation of the more general population is warranted. Second, multivariate regression analysis and Pearson's correlation coefficient showed a significant but weak degree of positive relationship between the IMF and age, suggesting that other independent associating factors still exist. For example, Hudson et al. reported that a higher BMI was associated with a lower IMF position in patients with macromastia [19], whereas no significant association was observed in our cohort. The degree of ptosis, macromastia, and weight of the breast are other potential parameters to be examined in the future. Further identification of associating factors may allow surgeons to estimate the ideal positions of the IMF based on a given set of values.

In conclusion, the TAP index, which can be easily obtained by anthropometric measurements, was defined as a new tool for evaluating the IMF. The index correlated with age and body position. Although further studies are needed, our results provide useful information for evaluation of the breast contour in a simple and objective manner.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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