



Comparison of the second and third intercostal spaces regarding the use of internal mammary vessels as recipient vessels in DIEP flap breast reconstruction: An anatomical and clinical study

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Background The purpose of this study was to compare the anatomical features of the internal mammary vessels (IMVs) at the second and third intercostal spaces (ICSs) with regard to their use as recipient vessels in deep inferior epigastric artery perforator (DIEP) flap breast reconstruction.

Methods A total of 38 consecutive DIEP breast reconstructions in 36 patients were performed using IMVs as recipient vessels between March 2017 and August 2018. The intraoperative findings and postoperative complications were analyzed. Anatomical analyses were performed using intraoperative measurements and computed tomography (CT) angiographic images.

Results CT angiographic analysis revealed the mean diameter of the deep inferior epigastric artery to be 2.42 ± 0.27 mm, while that of the deep inferior epigastric vein was 2.91 ± 0.30 mm. A larger mean vessel diameter was observed at the second than at the third ICS for both the internal mammary artery (2.26 ± 0.32 mm vs. 1.99 ± 0.33 mm, respectively; $P = 0.001$) and the internal mammary vein (IMV) (2.52 ± 0.46 mm vs. 2.05 ± 0.42 mm, respectively; $P < 0.001$). Similarly, the second ICS was wider than the third (18.08 ± 3.72 mm vs. 12.32 ± 2.96 mm, respectively; $P < 0.001$) and the distance from the medial sternal border to the medial IMV was greater (9.49 ± 2.28 mm vs. 7.18 ± 2.13 mm, respectively; $P < 0.001$). Bifurcations of the IMV were found in 18.4% of cases at the second ICS and in 63.2% of cases at the third ICS.

Conclusions The IMVs at the second ICS had more favorable anatomic features for use as recipient vessels in DIEP flap breast reconstruction than those at the third ICS.

Keywords Anatomy / Breast neoplasms / Breast reconstruction / Internal mammary arteries

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INTRODUCTION

Breast reconstruction surgery is becoming increasingly common [1]. The gold standard among breast reconstruction meth-

ods that utilize autologous tissue is deep inferior epigastric artery perforator (DIEP) flap reconstruction. While the thoracodorsal artery can be a recipient vessel for DIEP flap reconstruction, the internal mammary artery (IMA) has become the

most common recipient vessel. IMA perforators are also potential recipient vessels, and their superficial location results in better accessibility and allows dissection to be performed less invasively. However, the use of IMA perforators has not yet become standard and has only been described in a handful of studies with small sample sizes [2].

The use of the IMA and its perforators as recipient vessels has the following advantages. First, relative to the branches of the thoracodorsal axis, the caliber of the internal mammary vessels (IMVs) matches well with that of the deep inferior epigastric vessels. Second, IMVs are typically not involved in oncological breast surgery, and they are more easily accessed for microsurgery than the thoracodorsal branches [3]. Third, the inset of the flap to create a natural breast shape is easier to perform when using IMVs due to their medial location relative to thoracodorsal vessels. However, a disadvantage of the use of IMVs is that exposure of these vessels requires the excision of a section of costal cartilage, which may cause a contour defect in the medial area of the breast [4]. Additionally, the use of the IMA as a recipient vessel in breast reconstruction means that the vessel cannot be utilized subsequently for cardiac bypass [5].

In recent years, when IMVs were used as recipient vessels, a rib-sparing method was attempted to reduce morbidity. However, the partial or total resection of rib cartilage is necessary when the intercostal space (ICS) is too narrow for microvascular anastomosis to be performed. Exposure and dissection at either the second or the third ICS can be used for recipient vessel preparation in DIEP breast reconstruction. However, it has not been clearly elucidated whether the use of the second or third ICS is better for recipient vessel preparation in such reconstructions.

The purpose of this study was to investigate the anatomical and clinical characteristics of the second and third ICS in order to determine which is superior for recipient vessel dissection in DIEP flap reconstruction. This study focused in particular on the relative diameters of the second and third IMVs and the donor vessels of the DIEP flap.

METHODS

Retrospective analysis was performed of 38 DIEP flap breast reconstructions in 36 consecutive patients who underwent DIEP flap breast reconstruction at the investigators' hospital between March 2017 and August 2018. The study was approved by the institutional review board of the authors' institution (IRB No. 2020-04-013) and was performed in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from the patients.

When planning a DIEP flap reconstruction, preoperative

computed tomography (CT) angiography is performed to evaluate the donor and recipient sites and to obtain other information, thereby providing an effective guide to flap design and inset [6]. In the present study, all patients underwent preoperative CT angiography from 6 cm superior to the clavicle to the greater trochanter in a cranial to caudal direction to ensure that both the chest and abdomen were included. The INFINITT picture archiving and communication system (PACS; INFINITT Healthcare, Seoul, Korea) was used for measurements. Using preoperative CT angiography, the widths of the second and third ICS; the diameters of the IMA, internal mammary vein (IMv), deep inferior epigastric artery (DIEA), and deep inferior epigastric vein (DIEV); and the distance from the medial sternal border to the medial IMv were measured, and the presence of bifurcation of the IMv was assessed. IMv diameter was measured at the midpoint of the ICS. The diameters of the DIEA and the DIEV were measured approximately 1 cm above the origin to avoid sites of curvature of the vessels near their origin. In the INFINITT PACS (INFINITT Healthcare) program, the screen was magnified by a factor of 5.0, and values were measured using a two-dimensional ruler tool within the software (Fig. 1). Each variable was measured twice by each of two independent observers.

During surgery, the widths of the second and third ICS; the diameters of the IMA, IMv, DIEA, and DIEV; the distance from the medial sternal border to the medial IMv; and the presence of IMv bifurcation were evaluated directly in 11 patients (Fig. 2). The CT measurements and the intraoperative measurements were compared.

Statistical analysis was performed using SPSS software 18.0 (SPSS Inc., Chicago, IL, USA). All measurements were reported as means and standard deviations. Significance values were calculated using the independent t-test and the chi-square test. P-values < 0.05 were considered to indicate statistical significance.

RESULTS

Among the 38 cases, immediate reconstructions were performed in 68.4% (26/38), while delayed reconstructions were performed in the remaining 31.6% (12/38). Turbocharged bipedicle flaps were used in 10.5% of cases (4/38). The second ICS was chosen for recipient vessel dissection in 37 of the 38 cases; the only case in which the third ICS was chosen was one in which an inframammary incision had been used for the mastectomy. Total rib sparing using the second ICS was performed in 86.8% of cases (33/38), while partial or total segments of the third rib cartilage were resected in the remaining five cases (13.2%) (Table 1). End-to-end anastomosis was used for arteri-

Fig. 1. CT measurement of vessel diameter

(A) The internal mammary artery (IMA) at the second intercostal space (ICS) was visible on the cross-sectional computed tomography (CT) angiography image in a patient for whom the left internal mammary vessels were used as recipient vessels. The green arrow points the left IMA. (B) Measurement of the diameter of the IMA using a 2-dimensional (2D) ruler tool at $\times 5$ magnification. The green arrow points the left IMA. (C) The contralateral pedicle of the deep inferior epigastric artery perforator was used. The deep inferior epigastric artery (DIEA) was clearly visible approximately 1 cm above the origin. The green arrow points the right DIEA. (D) The diameter of the DIEA was measured using the 2D ruler tool at $\times 5$ magnification. The green arrow points the right DIEA.

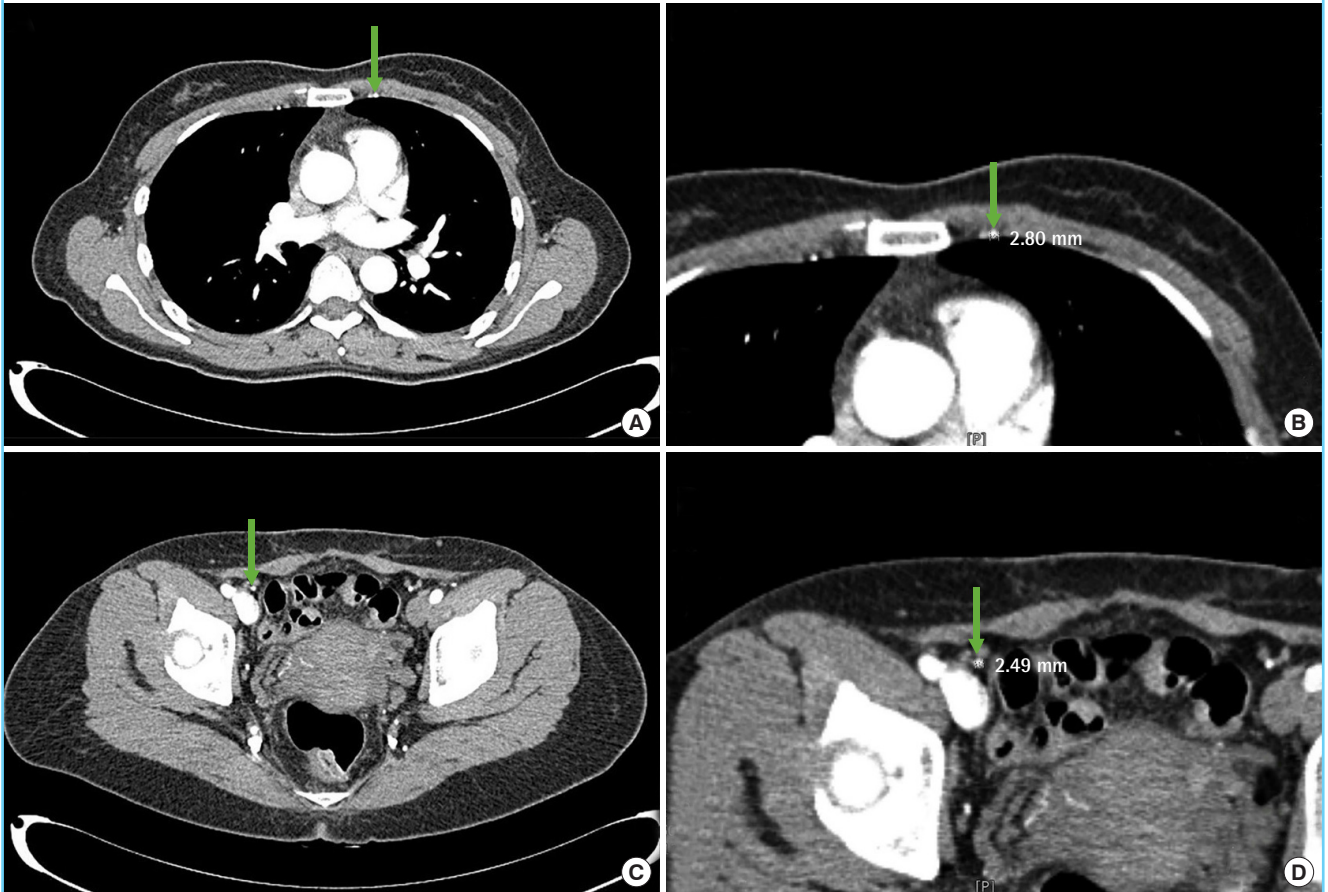


Fig. 2. Intraoperative measurement during DIEP breast reconstruction

(A) Direct intraoperative measurement of the diameter of the internal mammary vein using a ruler. (B) The second intercostal space was secured by retracting the skin flap using a skin hook and rubber band. DIEP, deep inferior epigastric artery perforator.

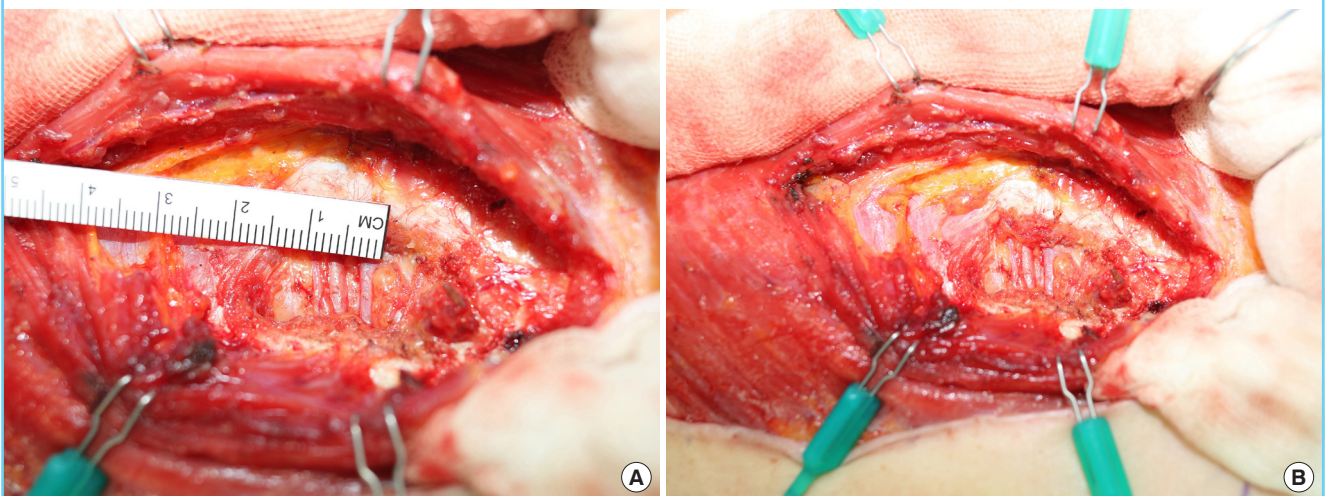


Table 1. Patient demographics and breast reconstruction types

Characteristic	Value
No. of patients	36
No. of breasts/flaps	38
Age at the time of surgery (yr)	
Mean ± SD	47.7 ± 6.0
Range	32–59
BMI (kg/m ²)	
Mean ± SD	24.6 ± 4.6
Range	18.6–37.9
Immediate reconstruction	26
Mastectomy weight, mean ± SD (g)	477.8 ± 235.5
Standard mastectomy	3
Nipple-sparing mastectomy	11
Skin-sparing mastectomy	12
Delayed reconstruction	12
Harvest flap weight, mean ± SD (g)	749.1 ± 306.9
Inset flap weight, mean ± SD (g)	474.8 ± 149.6
Inset rate, mean ± SD (%)	64.9 ± 15.4
ICS used for recipient vessels, No. (%)	
2nd ICS	37/38 (97.4)
3rd ICS	1/38 (2.6)
Total rib sparing, No. (%)	33/38 (86.8)
Partial resection of the rib cartilage, No. (%)	3/38 (7.9)
Total resection of the cartilage block, No. (%)	2/38 (5.3)

BMI, body mass index; ICS, intercostal spaces.

al and venous anastomosis in all cases. Postoperatively, no emergent re-operations were performed, and all flaps survived without partial or total flap loss.

CT angiographic analysis revealed that the IMA (2.26 ± 0.32 mm vs. 1.99 ± 0.33 mm, P = 0.001) and IMv (2.52 ± 0.46 mm vs. 2.05 ± 0.42 mm, P < 0.001) had larger mean diameters at the second than at the third ICS (Table 2). The ICS was wider (18.08 ± 3.72 mm vs. 12.32 ± 2.96 mm, P < 0.001) and the distance from the medial sternal border to the medial IMv was longer (9.49 mm vs. 7.18 mm, P < 0.001) at the second ICS than at the third. Bifurcations of the IMv were found in 18.4% of cases at the second ICS and in 63.2% at the third ICS. The mean diameter of the DIEA was 2.42 ± 0.27 mm, while the mean diameter of the DIEV was 2.91 ± 0.30 mm. This diameter was measured at 1 cm above the DIEA origin. These vessels were larger than the IMVs at the second and third ICS. The discrepancy in diameter between donor and recipient vessels was smaller at the second than the third ICS (Table 2).

The diameters of the donor and recipient vessels were measured intraoperatively and were compared with CT measurements. The measurement difference was calculated by subtracting the CT measurement from the intraoperative measurement. In the intraoperative measurements, the mean diameter of the IMA in the second ICS was 2.64 mm (mean difference from CT measurement, 0.44 mm), and the mean diameter of the DIEA

Table 2. Comparison of vascular anatomy in the second and third intercostal spaces in CT angiographic analysis (n=38)

Variable	2nd ICS (mm)	3rd ICS (mm)	P-value ^{a)}
Width of ICS	18.08 ± 3.72	12.32 ± 2.96	< 0.001
Diameter of IMA	2.26 ± 0.32	1.99 ± 0.33	0.001
Diameter of DIEA	2.42 ± 0.27		
Mean absolute differences of the artery diameters	0.37 ± 0.32	0.52 ± 0.38	0.002
Diameter of IMv	2.52 ± 0.46	2.05 ± 0.42	< 0.001
Diameter of DIEV	2.91 ± 0.30		
Mean absolute differences of the vein diameters	0.62 ± 0.42	0.89 ± 0.51	< 0.001
Distance from medial sternal border to medial vessel	9.49 ± 2.28	7.18 ± 2.13	< 0.001
Existence of IMv bifurcation	7 (18.4)	24 (63.2)	< 0.001

Values are presented as mean ± SD or number (%). The computed tomography (CT) measurement was performed on the surgical side (38 breasts in 36 patients). ICS, intercostal spaces; IMA, internal mammary artery; DIEA, deep inferior epigastric artery; IMv, internal mammary vein; DIEV, deep inferior epigastric vein. ^{a)}P-values were calculated using independent t-test and chi-square test.

Table 3. Comparison of CT measurements and intraoperative measurements

Variable	CT measurement (mm)	Intraoperative measurement (mm)	Differences (mm)	Absolute difference (mm)
IMA	2.19 ± 0.29	2.64 ± 0.25	0.44 ± 0.40	0.56 ± 0.20
IMv	2.14 ± 0.27	2.38 ± 0.47	0.24 ± 0.56	0.48 ± 0.35
DIEA	2.42 ± 0.22	2.41 ± 0.32	-0.01 ± 0.45	0.39 ± 0.20
DIEV	2.93 ± 0.39	2.43 ± 0.40	-0.49 ± 0.59	0.62 ± 0.45

Values are presented as mean ± SD. Difference was calculated by subtracting the computed tomography (CT) measurement from the intraoperative measurement. IMA, internal mammary artery; IMv, internal mammary vein; DIEA, deep inferior epigastric artery; DIEV, deep inferior epigastric vein.

was 2.41 mm (mean difference from CT measurement, -0.01 mm). The mean diameter of the IMv in the second ICS was 2.38 mm (mean difference from CT measurement, 0.24 mm), and the mean diameter of the DIEV was 2.43 mm (mean difference from CT measurement, -0.49 mm) (Table 3). However, as the mean difference was simply the average of the calculated differences, the values had the potential of canceling out and appearing misleadingly small. Therefore, the means and standard deviations of the absolute values were also calculated to better represent the actual differences between measurements.

The diameters of the IMVs were also compared between the right and left sides. At the second ICS, the mean diameter of the right IMA was 2.25 mm, and the mean diameter of the left IMA was 2.22 mm (P = 0.407). The mean diameters of the right and left IMVs were 2.61 mm and 2.32 mm, respectively (P = 0.038). Thus, IMv diameter was larger on the right side (Table 4).

Table 4. Comparison of computed tomography measurement values of both IMA and IMv diameter in second ICS

Diameter	Right (n = 23)	Left (n = 15)	P-value ^{a)}
IMA (mm)	2.25 ± 0.16	2.22 ± 0.11	0.407
IMv (mm)	2.61 ± 0.25	2.32 ± 0.14	0.038

Values are presented as mean ± SD.
 IMA, internal mammary artery; IMv, internal mammary vein; ICS, intercostal spaces.
^{a)}P-values were calculated using independent t-test and chi-square test.

DISCUSSION

In this study, anatomical analysis was used to determine that the second ICS had more preferable anatomical features for microanastomosis for DIEP flap breast reconstruction. The second ICS was used for recipient IMVs in 37 of the 38 cases, while the third ICS was used in a single case in which an inframammary incision had been used for nipple-sparing mastectomy. A total rib-sparing technique was possible in more than 80% of cases, and no microvascular complication developed in any of the 38 consecutive cases. Both the IMA and the IMv were larger in diameter at the second ICS than at the third ICS. The IMv at the third ICS was significantly smaller than at the second because it exhibited bifurcation in more than half of the cases (64.9%), while only 18.9% of cases displayed bifurcation at the second ICS. These anatomical features resulted in larger diameter discrepancies between the IMVs and the donor vessels of the DIEP flap at the third ICS than at the second ICS. At the second ICS, the ICS width was greater, and the distance from the medial sternal border to the medial IMv was longer. These characteristics allow vascular anastomosis to be performed more comfortably without rib resection.

Anatomical studies have reported that as the ICS number increases, the diameter of the blood vessels decreases, and bifurcation usually occurs at the fourth ICS. Arnez et al. [7] examined the IMVs at the third, fourth, and fifth ICS in fresh human cadavers. Of four potential patterns of venous anatomy, the most frequently observed was the extension of the IMv parallel with and medial to the IMA until the fourth ICS, at which point the IMv split into lateral and medial branches. The mean diameters of the IMv at the third, fourth, and fifth ICS were 2.8 mm, 2.6 mm, and 2.55 mm, respectively, while the analogous measurements of the IMA were 2.8 mm, 2.6 mm, and 2.6 mm, respectively. In another analysis of cadavers by Clark et al. [8], by the third rib, 90% of the left IMvs and 40% of the right IMvs were observed to bifurcate; additionally, most of the examined IMvs had decreased in diameter to 2 mm or smaller by the fourth rib. Kim et al. [6] conducted a preoperative CT angiographic evalu-

ation of IMVs at the second, third, and fourth ICS. At each, they measured the diameter of the IMA as well as the width and depth of the ICS for planning of DIEP flap breast reconstruction. Tuinder et al. [9] reported that the diameters of both the IMA and the IMv were 18% larger at the second ICS than at the third ICS [9]. However, no previous studies have compared the relative diameters of IMVs and pedicle vessels of the DIEP flap. In this study, we measured the diameters of both IMVs and DIEP pedicle vessels, and we found that the second ICS had a smaller discrepancy than the third in the diameters of the IMVs and the DIEP pedicle vessels.

In free flap surgery, a difference in diameter is often present between recipient vessels and flap vessels. According to a previous study, in 150 cases of microanastomosis, 33% of the artery and 50% of the vein anastomoses displayed vessel diameter discrepancy, which was defined as a graft-to-recipient diameter ratio greater than 1.5:1 or less than 1:1.5 [10]. It has been experimentally demonstrated that the patency of the anastomosis decreases as the diameter size discrepancy increases [11,12]. It can thus be concluded that a 1:1 ratio of graft-to-recipient diameter is ideal; barring this, a ratio of at least 0.75:1 should be ensured to attain satisfactory patency rates [12]. In this study, the diameter discrepancy of the IMv was 0.70:1 at the third ICS and 0.87:1 at the second ICS. The diameter discrepancy of the IMA was 0.82:1 at the third ICS and 0.93:1 at the second. Although different techniques can be used to overcome vessel diameter differences, microanastomosis of vessels with small diameter discrepancies can be performed more comfortably and is associated with a lower probability of technical error.

In their use of a rib-sparing approach, Sacks and Chang [13] initially accessed the IMVs via the third ICS, but they began using the second ICS due to its greater width and corresponding ease of access to the IMVs. However, skin-sparing mastectomy followed by immediate reconstruction may result in a skin opening of limited size, making the third ICS preferable to the second with regard to the performance of microvascular anastomosis. In this study, we used the second ICS as the recipient site in 37 of the 38 cases, and all patients survived without partial or total flap loss. The authors used a skin hook retractor connected to a rubber band to retract the skin flap, and the second ICS could be accessed in all cases (Fig. 2). In cases of nipple-sparing mastectomy, when the skin flap was not effectively retracted and it was difficult to access the second ICS, a 1- to 2-cm lateral extension of the lateral radial incision facilitated exposure of the second ICS.

Differences in vessel size between the right and left ICS have been reported. Tan et al. [14] reported that the right IMA tended to be larger than the left. On average, in that study, the right

side measured 2.25 cm and the left side measured 2.05 cm [14]. We similarly found the diameter of the right IMv to be statistically significantly larger than that of the left (2.61 mm vs. 2.32 mm, respectively; $P = 0.038$). In contrast, we found that the diameter of the IMA was not statistically significantly different between the right and left sides (2.25 mm vs. 2.22 mm, respectively; $P = 0.407$)

Total rib-sparing procedures were performed in 86.8% of all cases in this study, while partial or block resection of rib cartilages was performed in five cases. In those five cases, the mean ICS width was smaller (13.2 mm vs. 18.08 mm) and the mean body mass index (BMI) was higher (24.82 kg/m² vs. 24.35 kg/m²) than the mean values of the study population. In our experience, total rib sparing is possible when the ICS has a width of 14 mm or greater. In patients with relatively high BMIs, however, the second ICS tends to be deeply situated, making it difficult to access the IMVs.

It is of note that a single surgeon with less than 3 years of experience in microsurgical breast reconstruction performed all of the surgical procedures. However, no microvascular complications occurred in any of the 38 consecutive cases. This suggests that the IMVs of the second ICS are reliable recipient vessels even for inexperienced surgeons. Microvascular anastomosis can be performed more comfortably at the second than at the third ICS given that the IMVs have larger diameters that are similar to those of the DIEA and DIEV, the ICS is wider, and the distance from the sternal border to the IMVs is greater. Similar to our findings, a recent study reported that the second ICS was wider and the diameter of the IMv prior to bifurcation was larger, so use of the second ICS was recommended [15].

The revision rate of DIEP flaps is 3.38%. Venous insufficiency is the most common cause of revision, with a reported frequency of 86.7% [16]. When the recipient vein is significantly smaller than the donor vein, postoperative venous thrombosis can result. In our study, 64.9% of the IMVs in the third ICS were bifurcated, and the mean IMv diameter at the third ICS was significantly smaller than at the second. Even with vein couplers, it is known that the smaller the diameter, the greater the complications, such as venous insufficiency and fat necrosis [17].

Although the use of the second ICS has many anatomical advantages, it also carries disadvantages. The second ICS is located deeper or more upwardly slanted than the third, and exposure via a limited mastectomy incision can be difficult. Additionally, a longer pedicle is necessary, especially in low-set breasts. Therefore, selection of the level of the ICS in DIEP flap breast reconstruction must be individualized with consideration of various factors. Given that the optimal ICS could not be predicted using patient characteristics such as BMI and height, preoperative CT

angiographic evaluation of both recipient and donor vessels can be an effective way to choose the ICS for recipient vessels [6,18].

This study had several limitations. First, the sample size was relatively small; however, we were still able to identify a significant difference in the anatomical features of the second and third ICS. Second, there may have been errors in the measurement of vessel diameter using CT angiography. Since the course of the DIEA and DIEV near the origin are not straight, measurements of their diameter on CT images can be inaccurate. Similarly, CT angiography can be influenced by the density of the contrast medium, the size of the display field, and the wall thickness [19,20]. However, the purpose of this study was to identify relative differences in vascular diameter among the IMVs at the second ICS, the IMVs at the third ICS, and the pedicle vessels of the DIEP flap. Although differences could exist between the CT measurements and the actual diameters of the vessels, the uniformity of CT measurement allowed us to compare the relative diameters of the IMVs of the second and third ICS and the DIEP pedicle vessels.

The IMVs at the second ICS were found to have more favorable anatomic features for recipient vessels in DIEP flap breast reconstruction than those of the third ICS. Compared to the third ICS, the second ICS is wider, has a longer distance from the medial sternal border to the medial IMv, and has a lower likelihood of IMv bifurcation. Furthermore, the diameter of the IMv in the second ICS is similar to that of the DIEV.

NOTES

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Ethical approval

The study was approved by the Institutional Review Board of Ewha Womans University Mokdong Hospital (IRB No. 2020-04-013) and performed in accordance with the principles of the Declaration of Helsinki. Written informed consents were obtained.

Patient consent

The patients provided written informed consent for the publication and the use of their images.

Author contribution

Conceptualization: KJ Woo. Data curation: IH Seong, KJ Woo. Formal analysis: IH Seong, KJ Woo. Methodology: KJ Woo. Project administration: KJ Woo. Writing - original draft: IH

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