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Mapping lateral chest wall perforators: A cadaveric study on anatomical details for oncoplastic breast surgery☆

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Summary *Background:* Breast-conserving surgery is the standard treatment for early-stage breast cancer. Lateral chest wall perforator flaps (LCWPFs) provide effective volume replacement reconstruction that can preserve the latissimus dorsi (LD) muscle and minimize scarring. These region-based perforators include the lateral intercostal arterial perforators (LICAPs), lateral thoracic artery perforators (LTAPs), and septocutaneous thoracodorsal arterial perforators (sc-TDAPs). We examined the anatomical details of LCWPs in Thai cadavers, highlighting their clinical applications in oncoplastic breast surgery.
Methods: Colored silicone injections were introduced into the internal mammary and brachial arteries of 12 non-formaldehyde-preserved female cadavers. Suprafascial dissection was performed in the lateral decubitus position to identify perforators and their anatomical landmarks.
Results: A total of 120 perforators were identified, with a mean of 5 perforators per side. LTAPs were present in 96.8% of the sides, with 82.6% having a single perforator. LTAPs predominantly

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occurred in the 3rd intercostal space (53.6%), at a mean distance of 2.1 cm from the LD muscle. The lateral thoracic artery (LTA) originated from the axillary artery (90.5%), averaging 8.9 cm in length to the first perforator; LICAPs were mostly found at the 4th to 7th intercostal spaces and were located 2.2 cm from the LD muscle, whereas sc-TDAPs (16.67%) were present in the lateral chest wall region.

Conclusion: Our findings demonstrated the reliability of LCWPs, especially in the 3rd to 7th intercostal spaces. The length of LTA could be advantageous for distant flap movement in the reconstruction of inner breast defects. LCWPs for LCWPFs were reliable in all patients who underwent oncoplastic breast surgery especially when 2 consecutive intercostal spaces were included.

Breast-conserving surgery (BCS) has become the standard treatment for early-stage breast cancer[1]; however, conventional BCS in patients with high tumor-to-breast ratios or lower pole tumors could result in considerable deformities.[2] As patients increasingly prioritize their post-operative quality of life, there has been a discernible shift toward minimally invasive interventions, resulting in a growing preference for BCS and breast reconstruction. Both procedures require proficient oncoplastic surgical techniques to achieve optimal outcomes.[3] In oncoplastic surgery, the perforator flap is crucial because it facilitates less invasive and more intricate reconstruction procedures. This is accomplished by preserving major blood vessels and muscles through meticulous dissection of the intramuscular vessels.[4] The lateral chest wall perforator flap (LCWPF) is a volume replacement technique for oncoplastic breast surgery that can provide good cosmetic outcomes and fewer morbidities than the conventional latissimus dorsi (LD) muscle flap, thereby reducing donor site morbidity and lowering complication rates, while also concealing the scar.[5-7] LCWPFs are supplied by cutaneous perforators located between the anterior border of the LD muscle and anterior axillary lines or lateral breast creases, including lateral intercostal artery perforators (LICAP), lateral thoracic artery perforators (LTAP), and septocutaneous perforators of the thoracodorsal artery (sc-TDAP).[6]

LICAP flaps are based on the intercostal perforators originating from the costal groove.[8] This surgical method, which uses excess local tissue from the axilla and back and is supported by a robust vascular supply, is considered reliable.[9] Hamdi et al. previously described the anatomical location of LICAPs and their usage frequency in oncoplastic breast surgery.[8] LTAP flaps are based on single or multiple perforators of the lateral thoracic artery, which typically originate directly from the axillary artery, and occasionally from the thoracodorsal and subscapular arteries.[10-13] The lateral thoracic artery (LTA) is responsible for delivering blood to the lateral thorax tissue and plays a crucial role in women by supplying blood to the lateral breast and nipple-areolar complex.[14] Resection of the outer and central quadrants is most appropriately addressed using LICAP and LTAP.[15] Furthermore, LTAP flaps can function independently as the primary pedicle or in combination with LICAP flaps.[11] The anatomical and radiological details of LTAP have been studied in oncoplastic breast surgery and free-flap reconstruction.[16-18] Recently, Kagaya et al. demonstrated the presence of 50% sc-TDAPs and 90% LTAPs in the lateral thoracic region using magnetic resonance imaging.[16] The clinical applications of LCWPFs have been widely studied. Most previous cadaveric studies have demonstrated that these perforators are based on their main pedicles.[8,19] However, this is not applicable in current surgical applications where region-based perforators are used. Given the considerable variations in dimensions, quantity, and precise locations of LCWPs among individuals, thorough anatomical mapping is essential. This practice is vital to ensure the success of flap procedures and mitigate the risk of complications.[20]

Thus, we aimed to examine the anatomy of LCWPs in Thai cadavers to emphasize their anatomical details and focus on their clinical applications in oncoplastic breast surgery.

Patients and methods

Twelve adult female soft cadavers were dissected in this study. Self-curing colored silicone was injected into the internal mammary and brachial arteries with distal subclavian artery occlusion (25 mL each). The silicone was left to solidify for 24 h before dissection. The cadavers were positioned in the lateral decubitus position, with 90 ° of shoulder abduction during dissection, following the typical position used clinically. Suprafascial dissection commenced from the level of the axillary fold to the level of the inframammary fold, and dissection started from the tip of the scapula. LCWPs were carefully identified between the anterior border of the LD muscle and lateral breast crease using surgical loupes at 2.5× magnification. Significant perforators (> 0.5 mm) were identified by their distinctively colored silicone-labeled perforators and further dissected to confirm their origins. The number of perforators and their relationships with the intercostal spaces, anterior border of the LD muscle, and lateral breast creases were recorded. The LTA was further dissected to its origin, whether it arose from the thoracodorsal or axillary arteries, and its length was measured from the origin to the first branch of the LTAP. The study protocol was approved by the institutional review board of the Faculty of Medicine, Chulalongkorn University (Approval number: COE No.007/

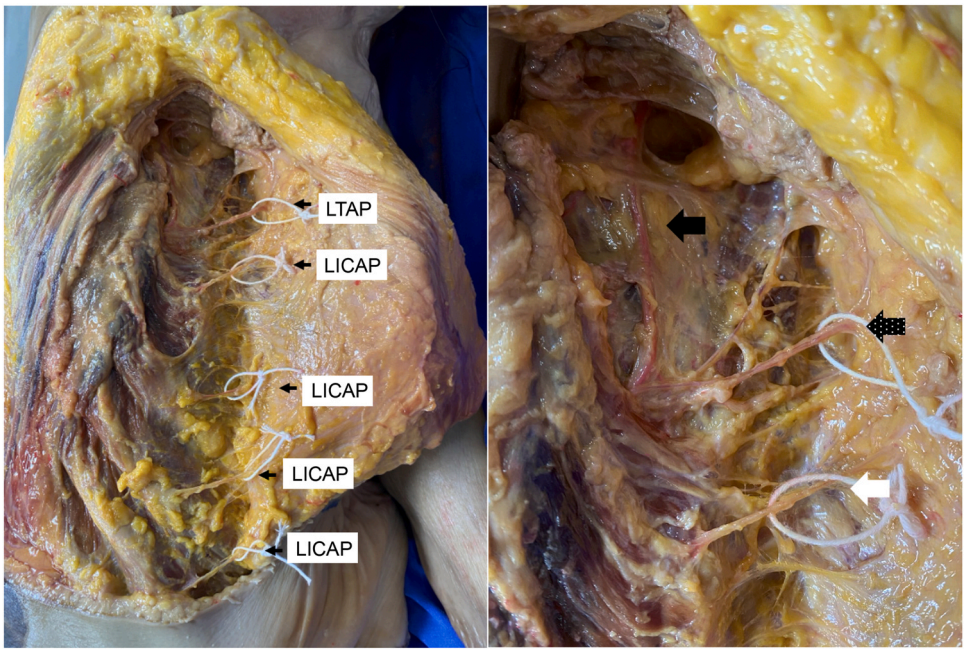

Figure 1 (Left) Lateral chest wall perforators on the right side are shown, including the LTAP on the 3rd intercostal space and LICAPs in the 4th, 5th, 7th, and 8th intercostal spaces. (Right) The dotted black arrow indicates the LTAP from the lateral thoracic artery (black arrow) arising from the axillary artery and a LICAP is indicated by the white arrow. Abbreviations: LICAP, lateral intercostal artery perforator; LTAP, lateral thoracic artery perforator.

2024). The manuscript was checked against the strengthening the reporting of observational studies in epidemiology (STROBE) checklist (Supplemental Appendix).

Data were analyzed using IBM SPSS version 25 (IBM, Chicago, IL, USA). Means, ranges, and percentages were used to describe the data.

Results

A total of 120 perforators were found on 24 sides of the 12 cadavers. The mean number of perforators per side was 5.0. The LCWPs identified in this study included LTAP (28, 23.3%), LICAP (88, 73.3%), and sc-TDAP (4, 3.3%). LTAPs were identified in 23 of the 24 sides (96.8%) (Figure 1). Among these, 1 perforator was found on 19 sides (82.6%) (Figure 1), 2 perforators on 3 sides (13.0%) (Figure 2), and 3 perforators on 1 side (4.3%) (Figure 2). The mean number of LTAPs was 1.2 per side. LTAPs were commonly found in the 3rd intercostal space (51.7%) and infrequently found in the 2nd and 4th intercostal spaces (20.7% and 17.2%, respectively). The mean distances from the anterior border of the LD muscle and lateral breast crease were 2.1 and 1.5 cm, respectively. The distribution of LTAPs and their distances from the LD muscle and lateral breast crease are shown in Table 1. The main LTA commonly originated from the axillary artery on 21 sides (91.3%) and infrequently originated from the thoracodorsal artery on 2 sides (8.7%), with a mean length of 8.9 cm (6–12.3 cm) from the origin to the first cutaneous perforator. In addition, sc-TDAPs were observed on 4 of the 24 sides (16.67%) (Figure 2).

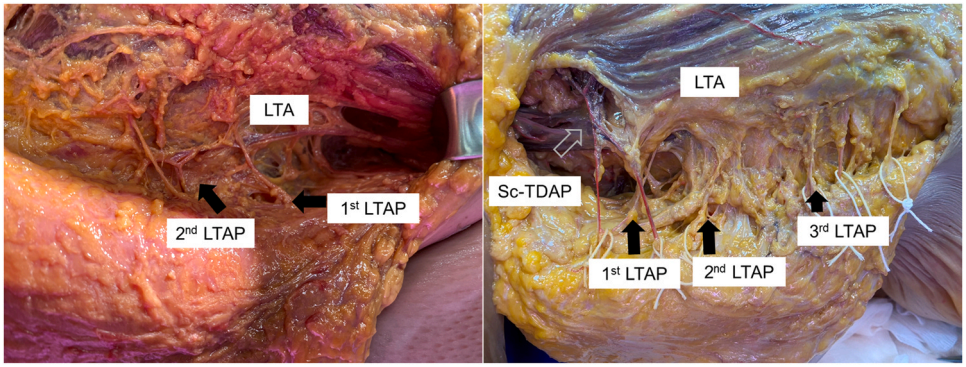

Figure 2 (Left) Right lateral chest wall region with an LTA and 2 branches of LTAPs. (Right) Left lateral chest wall region with an LTA, 3 branches of LTAPs, and sc-TDAP. Abbreviation: LTAP, lateral thoracic artery perforator; sc-TDAP, septocutaneous thoracodorsal arterial perforator.

Table 1 Distribution of LTAPs at the intercostal spaces and mean distances from the anterior border of the LD muscle and lateral breast crease.

	ICS 2	ICS 3	ICS 4	ICS 5
Number of LTAPs (%)	6 (21.4)	15 (53.6)	5 (17.9)	2 (7.1)
Mean and range distances from the LD muscle (cm)	2.6 (1.5–4)	1.9 (0.5–3.5)	2.3 (1.5–3.5)	2.4 (2.3–2.5)
Mean and range distances from the lateral breast crease (cm)	1.7 (0.9–25)	1.6 (0.5–2.7)	0.8 (0.5–1.8)	1.8 (1.5–2.4)

LTAPs, lateral thoracic artery perforators; LD, latissimus dorsi; ICS, intercostal space.

Table 2 Distribution of LICAPs according to intercostal spaces and mean distances from the anterior border of the LD muscle and lateral breast crease.

	ICS 3	ICS 4	ICS 5	ICS 6	ICS 7	ICS 8
Number of LICAPs (%)	9 (10.2)	18 (20.5)	17 (19.3)	18 (20.5)	18 (20.5)	8 (9)
Mean and range distances from the LD muscle (cm)	1.4 (0.5–2)	2.0 (1–3)	2.2 (0.5–3.9)	2.2 (0.5–3)	2.7 (1.5–4)	2.3 (0.5–3.5)
Mean and range distance from the lateral breast crease (cm)	1.7 (0.3–4)	1.6 (0.5–3.2)	1.4 (0.5–2.5)	1.5 (0.5–4)	1.4 (0.5–3.5)	1.9 (1–4)

LICAPs, lateral intercostal artery perforators; LD, latissimus dorsi; ICS, intercostal space.

LICAPs were identified on 24 sides and commonly found in the 4th, 5th, 6th, and 7th intercostal spaces, with occurrences of 20.5%, 19.3%, 20.5%, and 20.5%, respectively. The mean number of LICAPs was 3.6 per side. The mean distances from the LD muscle and lateral breast crease were 2.2 and 1.5 cm, respectively. The distribution of LICAPs and distances from the LD muscle and lateral breast crease are shown in Table 2.

In combination, LTAPs, LICAPs, and sc-TDAPs were found to be the main perforator system in the lateral chest wall region (Figure 3). The most abundant perforator was LICAPs, followed by LTAPs and sc-TDAPs. The LCWPs were present in the 2nd (29.2%), 3rd (87.5%), 4th (87.5%), 5th (79.2%), 6th (75%), 7th (75%), and 8th (33.3%) intercostal spaces (Table 3). Among these, LTAPs and sc-TDAPs were present between the 2nd and 5th intercostal spaces, with the dominant area being the 3rd intercostal space. The abundance of LCWPs was found in the 3rd–7th intercostal spaces, which showed a > 75% probability of having at least 1 perforator. Interestingly, the presence of LCWPs in 2 consecutive intercostal spaces from the 2nd to 7th intercostal spaces was approximately 100% and 1 to 2 perforators were observed. The average distance from the lateral breast crease was 1.5 cm for LTAPs, 1.6 cm for LICAPs, and 2.2 cm for sc-TDAPs. In the meantime, the distance from the LD muscle was closer for sc-TDAP, while LTAPs and LICAPs were found at a comparable distance in the anteroposterior aspect.

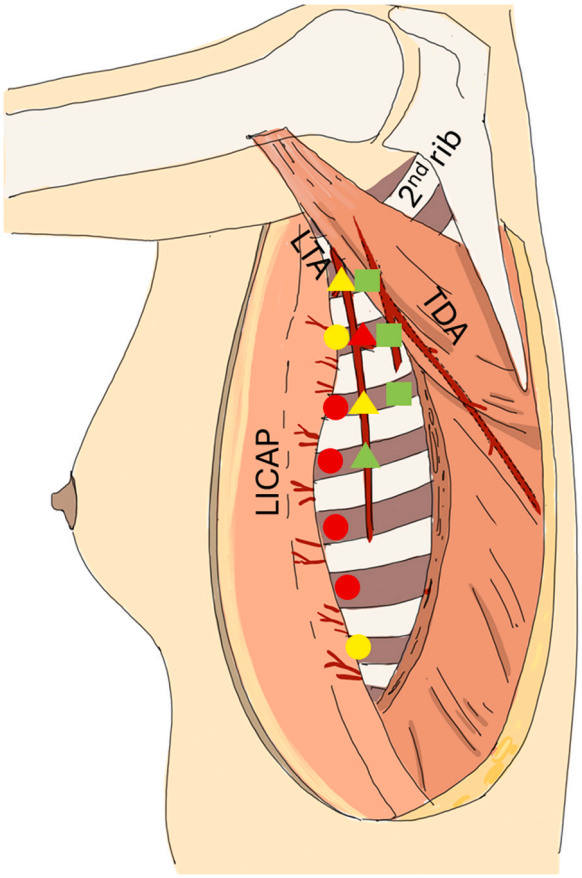

Figure 3 Illustration of the lateral chest wall region with a LICAPs (circles), LTAPs (triangles), and sc-TDAPs (squares) between the 2nd ICS to 8th ICS and a heatmap of the abundance of these perforators. Red indicates ≥50%, Yellow indicates 10%–49%, and Green indicates < 10%.
Abbreviations: LICAP, lateral intercostal arterial perforator; LTAP, lateral thoracic artery perforator; sc-TDAP, septocutaneous thoracodorsal arterial perforator.

Discussion

In BCS, patients with < 20% breast defects or those with larger breast volumes can benefit from volume displacement techniques, including simple wide excision or therapeutic mammoplasty, with favorable outcomes.[6] However, for larger defects or small breast volumes, autologous tissue is required to fill the defects properly and achieve

Table 3 Numbers, percentages, and ratios of LCWPs according to intercostal spaces and 2 consecutive intercostal spaces.

ICS	LICAP		LTAP		sc-TDAP		LCWP	
	Cadaveric side (%)	N (per side ratios)	Cadaveric side (%)	N (per side ratios)	Cadaveric side (%)	N (per side ratios)	Cadaveric side (%)	N (per side ratios)
2nd ICS	0	0	6 (25%)	6 (0.3)	1 (4.2%)	1 (0.04)	7 (29.2%)	7 (0.3)
3rd ICS	9 (37.5%)	9 (0.4)	15 (62.5%)	15 (0.6)	2 (8.3%)	2 (0.1)	21 (87.5%)	26 (1.1)
4th ICS	18 (75%)	18 (0.8)	5 (20.8%)	5 (0.2)	1 (4.2%)	1 (0.04)	21 (87.5%)	24 (1)
5th ICS	17 (70.8%)	17 (0.7)	2 (8.3%)	2 (0.1)	0	0	19 (79.2%)	19 (0.8)
6th ICS	18 (75.0%)	18 (0.8)	0	0	0	0	18 (75.0%)	18 (0.8)
7th ICS	18 (75.0%)	18 (0.8)	0	0	0	0	18 (75.0%)	18 (0.8)
8th ICS	8 (33.3%)	8 (0.3)	0	0	0	0	8 (33.3%)	8 (0.3)
2nd–3rd ICS	9 (37.5%)	9 (0.4)	21 (87.5%)	21(0.9)	3 (12.5%)	3 (0.1)	24 (100%)	33 (1.4)
3rd–4th ICS	22 (91.7%)	27 (1.1)	17 (70.8%)	20 (0.8)	3 (12.5%)	3 (0.1)	24 (100%)	49 (2.0)
4th–5th ICS	21 (87.5%)	35 (1.5)	6 (25.0%)	7 (0.3)	1 (4.2%)	1 (0.04)	24 (100%)	43 (1.8)
5th–6th ICS	21 (87.5%)	35 (1.5)	2 (8.3%)	2 (0.1)	0	0	23 (95.8%)	37 (1.5)
6th–7th ICS	24 (100%)	36 (1.5)	0	0	0	0	24 (100%)	36 (1.5)
7th–8th ICS	21 (87.5%)	26 (1.1)	0	0	0	0	21 (87.5%)	26 (1.1)

LICAP, lateral intercostal artery perforator; LTAP, lateral thoracic artery perforator; sc-TDAP, septocutaneous thoracodorsal artery perforator; LCWP, lateral chest wall perforator; ICS, intercostal space; Cadaveric side = numbers and percentages of cadaveric side with a presence of at least 1 perforator; N = number of total perforators.

acceptable cosmetic outcomes.[2,21] LCWPFs have been widely used after BCS for decades. Compared to the conventional LD flap, LCWPFs are advantageous because of their proximity to the donor site and its pedicle and resultant acceptable scars,[8] and previous studies have reported oncological safety and favorable patient satisfaction.[6,7,22-24] In real-world practice, Agrawal et al. conducted a multicenter study that retrospectively reviewed 505 cases of LCWPFs and found that LICAP, LTAP, and their combinations were used in 54%, 4.4%, and 19.8% of the cases, respectively.[25] This emphasizes the importance of region-based perforators, which were examined in our study as an entire system in the lateral chest wall region, for oncoplastic breast surgery.

After the introduction of lateral thoracic random flaps in 1986,[26] Hamdi et al. detailed the anatomical features of LICAP, and it was first described as a fasciocutaneous flap for lateral breast defects, highlighting the advantages of sparing the LD muscle.[8] In our study, we found 5 perforators on one side of each cadaver, roughly 1 perforator more than the previous findings by Hamdi et al.[8] The additional perforator was likely due to the inclusion of LTAP, which is important in real practice.[6,11] The use of color-labeled materials facilitated the detection of these perforators and allowed us to identify dominant perforators in all cadaver sides compared to 92% in a previous report.[8] In our study, the LICAPs were equally distributed between the 4th–7th intercostal spaces, and 4th intercostal LICAP was more abundant than that in the previous study.[8] Although the dominant intercostal space could not be identified, reliability was high between the 4th to 6th intercostal spaces. Accordingly, the inclusion of at least 2 intercostal spaces was reasonable when LICAPs were planned for use as the main perforator. However, a preoperative pinch test continues to be essential to evaluate the estimated flap area.

LTAP for lateral breast reconstruction was first described by McCulley et al.[11] LTAP has a transpositional capability as a pendulum when dissected toward its pedicle, making it suitable for reconstructing distant regions such as the upper-inner breast defects, whereas LICAP is limited to use as a turnover or propeller flap. We found that the presence of LTAP was 95% in the lateral chest wall region, predominantly located in the 2nd to 4th intercostal spaces, with a mean of 1.2 LTAPs per side. The most common location was at the 3rd intercostal space. The high distribution of LTAPs was similar to that reported in a previous Asian radiological study and another cadaveric study,[16,18] but seemed slightly higher than those obtained in a previous study by McCulley et al.[11] This might be due to differences in ethnicity and appeared to be prominent in the Asian population. Additionally, we found that the mean LTA length was 8.9 cm from the origin to first perforator, whereas Taweepraditpol et al. found 2.2 LTAPs per side via cadaveric dissection and 1.3 LTAPs per side using computed tomography angiography, with a mean LTA length of 11.7 cm.[18] In clinical use, the length from the origin of the LTA to the first branch appears to be the expected distance for transposition, and the pedicle needs to be preserved during axillary dissection when LTA or LTAP is planned for reconstruction.[27] However, McCulley et al. described using LTAPs harvested from the lower lateral chest wall, where the main LTA may be obliterated. Although this approach could increase pedicle length, dissection of the main LTA appears more challenging than using the superior branch of the LTAPs.[11] Additionally, sc-TDAP is an important perforator in this area; we observed an incidence of 16.67% sc-TDAPs in the lateral chest wall region. This appears to be slightly lower than those in other studies (ranging from 40% to 60% in pedicle-based studies).[16,28,29] Studies on region-based perforators might lower the actual number of sc-TDAPs because the sc-TDAPs that bifurcated near the axillary artery, from the serratus anterior branch, or coursed over the muscle were outside our area of interest and were excluded from the study.[29] The use of sc-TDAP for oncoplastic breast reconstruction is feasible; however, a longer distance must be considered from the perforator to the defects for transposition.

The anatomical landmark details in our study did not differ from those in previous studies.[6,8,11] The LTAP was found 2.1 cm anterior to the LD muscle and 1.5 cm posterior to the lateral breast crease; in several studies, the surgical landmarks were observed 2 cm anterior to the LD muscle and 1 to 2 cm posterior to the lateral breast crease.[6,11] LICAPs were commonly found at the 4th to 7th intercostal spaces and were located 2.2 cm anterior to the LD muscle and 1.5 cm posterior to the lateral breast crease. These perforators were located caudal to the LTAPs. However, these distances were narrower than those reported by Hamdi et al. This finding may be attributed to the smaller average dimensions of this anatomical region in the Asian population.[8] Interestingly, the lower LCWPs were located more distant to LD muscle and more adjacent to the lateral breast crease. This can facilitate the flip-over approach at the lower outer part of the breast.[6,11,30]

Based on our findings, we propose that LCWPs are reliable for all patients requiring oncoplastic breast surgery, and an average of 5.0 perforators per side can be expected. Currently, handheld vascular Doppler could help locate the main perforator, and high-frequency ultrasound could help visualize these perforators preoperatively.[23,31] Additionally, preoperative breast MRI can also identify the origins and interconnections of LCWPs; however, the most critical aspect is ensuring the intraoperative identification of perforators and meticulous axillary surgery.[17] Accordingly, accurate anatomical knowledge of these perforators is crucial to facilitate surgical dissection. Indocyanine green angiography has been used to assess intraoperative perfusion.[32] This might help reconfirm an area of perfusion or predict post-operative complications, but it cannot guide surgical dissection.[33,34]

The perforators described above are most commonly used for partial breast reconstruction. Owing to its reliability and low donor site morbidities, LCWPF has become a preferred reconstruction technique in several breast cancer centers[24,30,35] and could lower mastectomy rates and result in high patient satisfaction scores.[23,35] The abundance of LCWPs in the 2nd to 4th intercostal spaces makes them most compatible and preferable for reconstructing upper-outer breast defects. However, the reliability of LCWPs in the 5th to 7th intercostal spaces justifies their use for lower outer defects. The inclusion of 2 consecutive intercostal spaces is recommended to ensure the highest probability of retrieving at least 1 to 2 perforators, particularly in the 5th to 8th intercostal spaces. Additionally, the longer pedicle of the sc-TDAP and LTAP makes them suitable for inner-area defects or for flaps requiring skin coverage. Currently, flap harvesting is designed to improve cosmetic outcomes, particularly in the lower outer part of the breast. Meybodi et al. modified the LICAP flap design into a lazy “S” shape along the inframammary fold and lower axilla to conceal the scar along the breast crease and prevent position changes during surgery.[36] Yee et al. designed a LICAP flap toward the axilla to facilitate the reconstruction of the inner quadrant and total mastectomy defects.[37] In addition to oncoplastic breast surgery, Kagaya et al. used LTAPs and sc-TDAPs for free-flap reconstruction based on the thoracodorsal and lateral thoracic vessels.[16]

In conclusion, LCWPs include LTAPs, LICAPs, and sc-TDAPs. These perforators were reliably found between the 3rd to 7th intercostal spaces and an average of 5 perforators per side was observed. LTAP was frequently found and can be used for distant transposition, while sc-TDAP can serve as an alternative for this purpose. For surgical applications, the inclusion of 2 consecutive intercostal spaces is recommended, as it considerably increases the reliability of perforator retrieval. These perforators were abundant and consistent in Thai cadavers, supporting their safe and effective use for oncoplastic breast reconstruction.

Ethical approval

The study protocol was approved by the Institutional Review Board of Faculty of Medicine, Chulalongkorn University approved the study (Approval number: COE No.007/2024).

Funding

None.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of Competing Interest

None.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.bjps.2025.09.020.

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