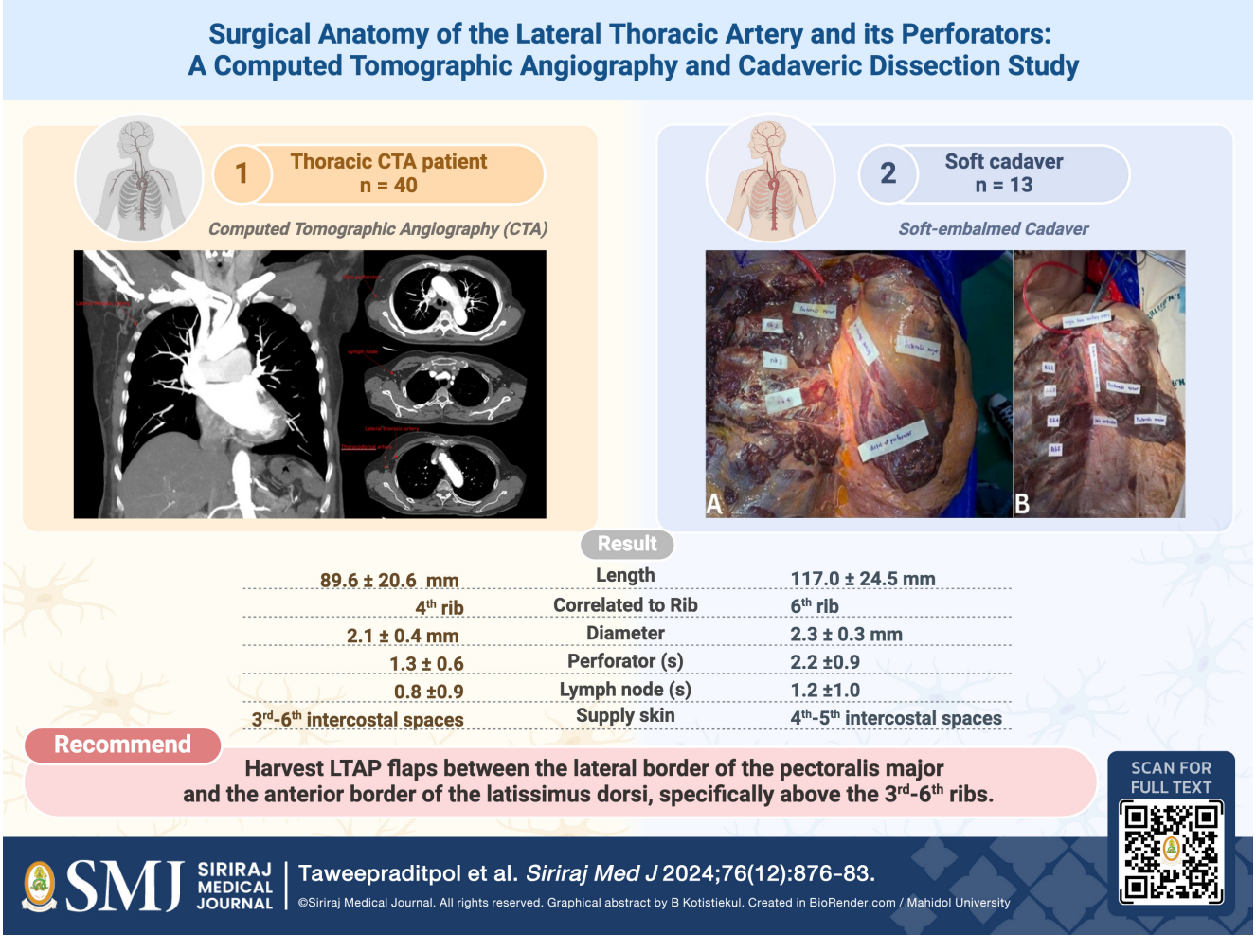
Surgical Anatomy of the Lateral Thoracic Artery and Its Perforators: A Computed Tomographic Angiography and Cadaveric Dissection Study

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Received 13 August 2024 Revised 10 October 2024 Accepted 10 October 2024
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https://doi.org/10.33192/smj.v76i12.270603

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ABSTRACT

Objective: This study explores the anatomical variations and characteristics of the lateral thoracic artery (LTA) and its perforators through thoracic computed tomographic angiographies (CTA) and cadaveric dissection, aiming to enhance surgical planning and patient outcomes.

Materials and Methods: Data were recorded for both thoracic CTA patients (n = 40) and soft cadavers (n = 13) for subsequent retrospective analyses of biological sex, age, body mass index (BMI), LTA characteristics (length, diameter, origin, number of perforators, number of lymph nodes), and locations (rib level and distance from the pectoralis major, latissimus dorsi, and acromioclavicular joint).

Results: Average LTA parameters for thoracic CTAs were 89.6 millimeters in length from origin and 2.1 millimeters in diameter, while cadavers were 117.0 millimeters in length and 2.3 millimeters in diameter. At least 1-2 cutaneous perforators and 1 proximal lymph node were found across both thoracic CTAs and cadavers. No significant differences were observed between the left and right sides for both groups. On average, 73.8% and 66.4% of LTAs from thoracic CTAs and cadavers, respectively, originated from the axillary artery.

Conclusion: This knowledge is crucial for surgical planning, both to minimize damage to the LTA and ensure the inclusion of its perforators and proximal lymph nodes in the lateral thoracic region. The researchers recommend lateral thoracic artery perforator flap harvest between the lateral border of the pectoralis major and the anterior border of the latissimus dorsi, specifically above the 3rd-6th ribs, which is correlated to the length of LTA at 89.6-117 millimeters from origins.

Keywords: Lateral thoracic artery; LTA Perforators; cadaveric dissection; CTA (Siriraj Med J 2024; 76: 876-883)

INTRODUCTION

Perforator flaps are now preferred over traditional reconstructive microsurgery methods due to their minimally invasive nature. These flaps consist of pedicle and soft tissue, harvested without sacrificing muscle or major vessels, thereby preserving surrounding tissue vasculature[1] and reducing functional loss and site-specific morbidities.[2] Developed in the late 1980s, the technique began with the inferior epigastric artery skin flap, which used only skin and subcutaneous adipose tissue, excluding the rectus abdominus muscle.[3,4]

The lateral thoracic artery perforator (LTAP) flap is based on the lateral thoracic pedicle and supplied by the lateral thoracic artery (LTA),[1,5-7] which typically arises from the axillary artery and sometimes from the subscapular and thoracodorsal arteries.[8-10] The LTA runs parallel to the lateral border of the pectoralis major and the anterior border of the latissimus dorsi on the serratus anterior fascia.[11] It supplies the serratus anterior, pectoralis major, pectoralis minor, subscapularis, as well as perforators of the direct cutaneous branch that lie perpendicular and supply the skin of the lateral thoracic region.[7,9,12,13] LTAP flaps are commonly used in conservative breast surgery (CBS) reconstruction for secondary defects or breast cancer.[11,14] Some studies have noted that vascularized lymph node transfer (VLNT) through LTAP or thoracodorsal artery perforator (TAP) flaps can achieve lymph flow restoration for patients with lymphedema.[15,16]

LTAP flaps offer several advantages over lateral intercostal artery perforator (LICAP) flaps. They conserve most of the lateral breast fold and can have scars concealed from LTAP flap harvest concealed by a bra strap.[11] The LTAP flap's pedicle partial or complete mobilization allows for greater reach and transposition for distant defect reconstruction compared to the LICAP flap.[11] Additionally, LTAP flaps result in minimal donor site morbidity and functional loss, preserved vasculature, and muscle tissue, leading to rapid recovery.[3,11,12] They are easy to harvest with the patient in a supine or lateral position and are effective in VLNT for lymphatic channels and lymph node (LN) present in the lateral thoracic region for lymphedema.[15-17] These findings support the use of LTAP flaps for reconstructive and plastic surgery through its numerous applications in wound closure.[5] However, research on LTAP flaps is limited due to few studies exploring its anatomical variations, characteristics, dimensions, and landmarks.[7] Characterizing the anatomical location and physiology of vasculature in the lateral thoracic region would help minimize the risk of damaging LTA and LTAP tissue during flap harvest.

This study aims to address a gap in literature by examining surgical anatomical characteristics, dimensions, and landmarks of the LTA and its perforators using thoracic computed tomographic angiographies (CTAs) and cadaveric dissection.

MATERIALS AND METHODS

This study was approved by the Siriraj Institutional Review Board, protocol number COA no. Si 420/2022.

Clinical studies

Clinical assessments of the LTA were conducted using 40 thoracic CTAs (80 sides) from Siriraj Hospital's Picture Archiving and Communication System (PACS), collected between January and December 2021, by the Siriraj Radiology Department (SIRAD). Healthy patients over 18 years of age, with no history of congenital or acquired thoracic anomalies, surgeries, or radiology of the breast and thorax were included in this retrospective assessment.

Cadaveric studies

Angiography assessments of the LTA were performed on 13 soft-embalmed cadavers (26 sides) dissected between July and December 2022 by Plastic surgeons from Division of Plastic Surgery, Department of Surgery, Siriraj Hospital and certified anatomist from the Department of Anatomy, Siriraj Training and Education Center for Clinical Skills (SiTEC), Siriraj Hospital. The epidermis, dermis, and subcutaneous layers were well-preserved.[18] Radio-dense silicone oil (3:1) was injected directly into the axillary artery through the costoclavicular space. The surgical approach involved trap-door thoracotomies with a transverse incision superior to the clavicle, descending to the midline sternum to the 10th interspace, and then laterally to the anterior-axillary line.[19] Individual tissue layers were carefully excised to expose the LTA and its perforators, minimizing damage to the vasculature.

Statistical analyses

All data was tested with test of normality. Descriptive statistics were used to describe baseline characteristics (age, weight, height, BMI). Data are presented as means with standard deviation or frequencies with percentages as appropriate. For normal distribution data, we used the paired sample T-test to compare between left and right side of cadaver-cadaver, CTA-CTA, and used independent sample T-test to compare between left and right side of cadaver-CTA (length, diameter, and distance from the lateral border of the pectoralis major, anterior border of the latissimus dorsi, and acromioclavicular joint). For non-parametric test the study used Wilcoxon test to compare between left and right side of cadaver-cadaver, CTA-CTA, and used Mann-Whitney U test to compare between left and right side of cadaver-CTA to describe LTA characteristics (number of perforators, number of LNs). A P-value <0.05 was set as the threshold for statistical significance. SPSS program version 18 was used for all statistical analyses. Pearson's correlation assessed the correlation between LTA and its perforators across both groups.

RESULTS

Demographic data

The thoracic CTA patients were 52.5% male (n = 21), with a mean (SD) age of 67 (11.9) years and a BMI of 24.5 (3.5) kg/m^2. Among the cadavers, 46.2% were male (n = 6), with an average age of 72 (8.0) years and a BMI of 23.0 (2.5) kg/m^2. No significant demographic differences were observed between groups (Table 1).

Clinical studies

No significant differences in LTA parameters were found between left and right thoracic CTAs (Table 2). Average LTA parameters were: length from origin, 89.6 ± 20.6 millimeters, diameter, 2.1 ± 0.4 millimeters, distance from the acromioclavicular joint, 136.6 ± 22.7 millimeters, distance from the lateral border of the pectoralis major, 5.3 ± 0.7 millimeters, and distance from the anterior border of the latissimus dorsi, 36.0 ± 13.2 millimeters. Approximately 1 perforator (1.3 ± 0.6) and 1 LN (0.8 ± 0.9) were found across both left and right lateral thoracic regions. Right perforators typically supplied skin between the 7.5-11 centimeters (4th-5th intercostal spaces), while left perforators typically supplied skin between the 6.0-12.0 centimeters (3rd-6th intercostal spaces) (Fig 1).

Cadaveric studies

No significant differences in left and right LTA parameters were observed in cadavers (Table 2). Average LTA parameters were: length from origin, 117.0 ± 24.5 millimeters, diameter, 2.3 ± 0.3 millimeters, distance from the acromioclavicular joint, 168.3 ± 17.4 millimeters, distance from the pectoralis major, 3.8 ± 0.7 millimeters, and distance from the latissimus dorsi, 37.9 ± 6.5 millimeters. Approximately 2 perforators (2.2 ± 0.9) and 1 LN (1.2 ± 1.0) were found across both left and right lateral thoracic regions. Right (Fig 2A) and left (Fig 3A-B) perforators, 0.3-0.5 millimeters in diameter, and 2.0 millimeters in length were typically observed supplying the skin between the 4th-5th intercostal spaces. Lateral thoracic LNs were also observed proximal to these vascular structures (Fig 2B).

Pearson's correlation

LTA length from origin ($p < 0.01$), distance from the acromioclavicular joint ($p < 0.008$), and number of cutaneous perforators ($p < 0.005$) were significantly greater in cadavers than in thoracic CTAs (Table 3).

TABLE 1. Patient demographic data.

Variable		Thoracic CTA	Cadavers	*p*-value
Age (yrs, mean ± SD)		67.1 ± 11.9	72.7 ± 8.0	0.120
Sex n (%)	Male female	21.0 (52.5) 19.0 (47.5)	6.0 (46.2) 7.0 (53.8)	0.671
Weight (kg, mean ± SD)		63.9 ± 11.0	60.8 ± 12.2	0.397
Height (cm, mean ± SD)		160.2 ± 10.6	161.8 ± 10.0	0.648
BMI (kg/m^2, mean ± SD)		24.5 ± 3.5	23.0 ± 2.5	0.160

Abbreviations: SD, Standard Deviation; BMI, Body Mass Index.

TABLE 2. Patient demographic data.

Variable	Side	Mean ± SD	*p*-value
From thoracic CTA (n = 40)			
Length from origin (mm.)	Right Left	91.6 ± 20.8 87.5 ± 20.4	0.374
Diameter (mm.)	Right Left	2.1 ± 0.4 2.0 ± 0.4	0.095
Distance from acromioclavicular joint (mm.)	Right Left	139.8 ± 23.4 133.5 ± 22.0	0.210
Distance from lateral border of pectoralis major (mm.)	Right Left	6.1 ± 0.8 4.5 ± 0.5	0.339
Distance from anterior border of latissimus dorsi (mm.)	Right Left	36.5 ± 13.4 35.5 ± 13.0	0.746
Number of perforators	Right Left	1.4 ± 0.7 1.2 ± 0.4	0.119
Number of lymph nodes	Right Left	0.8 ± 0.8 0.8 ± 1.0	0.807
From cadaveric dissection (n = 13)			
Length from origin (mm.)	Right Left	125.7 ± 26.0 108.2 ± 23.0	0.132
Diameter(mm.)	Right Left	2.3 ± 0.4 2.2 ± 0.2	0.424
Distance from acromioclavicular joint (mm.)	Right Left	170.6 ± 17.7 165.9 ± 17.1	0.553
Distance from lateral border of pectoralis major (mm.)	Right Left	3.4 ± 0.7 4.1 ± 0.7	0.848
Distance from anterior border of latissimus dorsi (mm.)	Right Left	38.6 ± 6.6 37.1 ± 6.3	0.579
Number of perforators	Right Left	2.0 ± 0.8 2.4 ± 1.0	0.281
Number of lymph node	Right Left	1.5 ± 1.2 0.9 ± 0.8	0.244

All specified lengths, diameters, and distances are in millimeters (mm).
Abbreviations: SD, Standard Deviation; CTA, Computed Tomography Angiography.

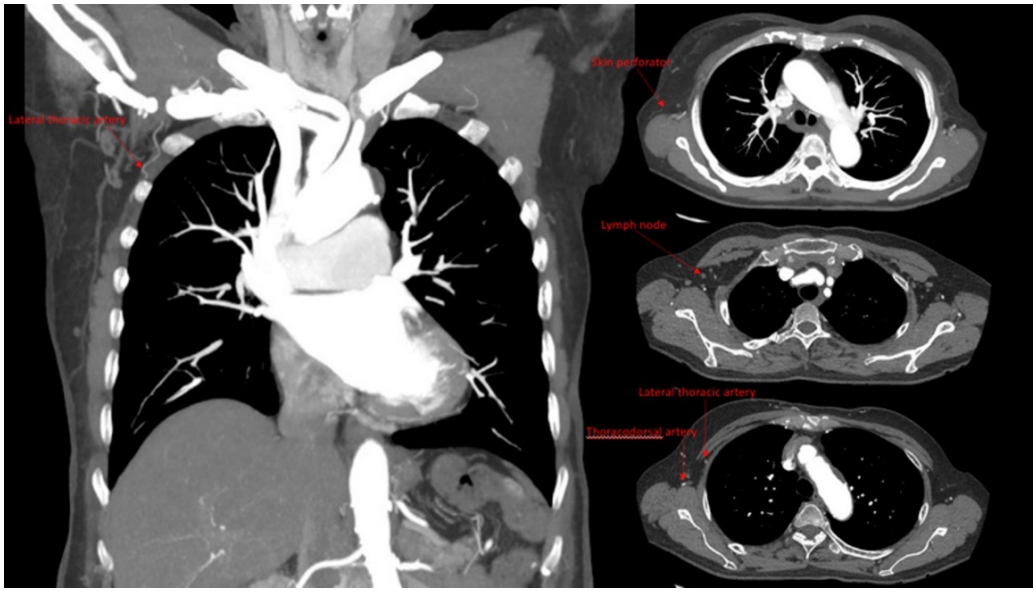


Fig 1. Thoracic computed tomography angiography (CTA) of the right lateral thoracic artery (LTA).

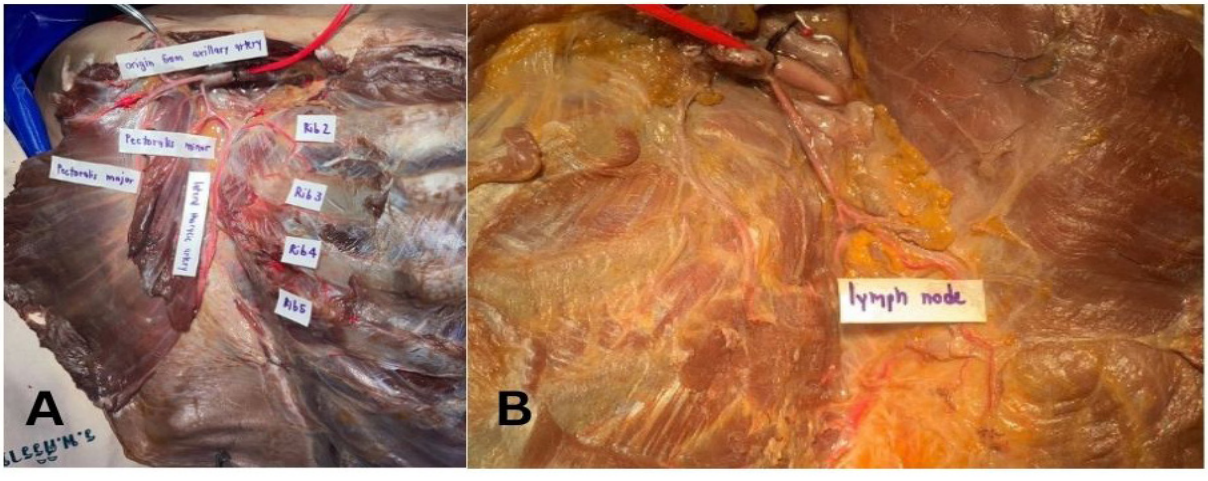


Fig 2. Cadaveric dissection of the (A) right lateral thoracic artery (LTA) and (B) lateral thoracic lymph node.

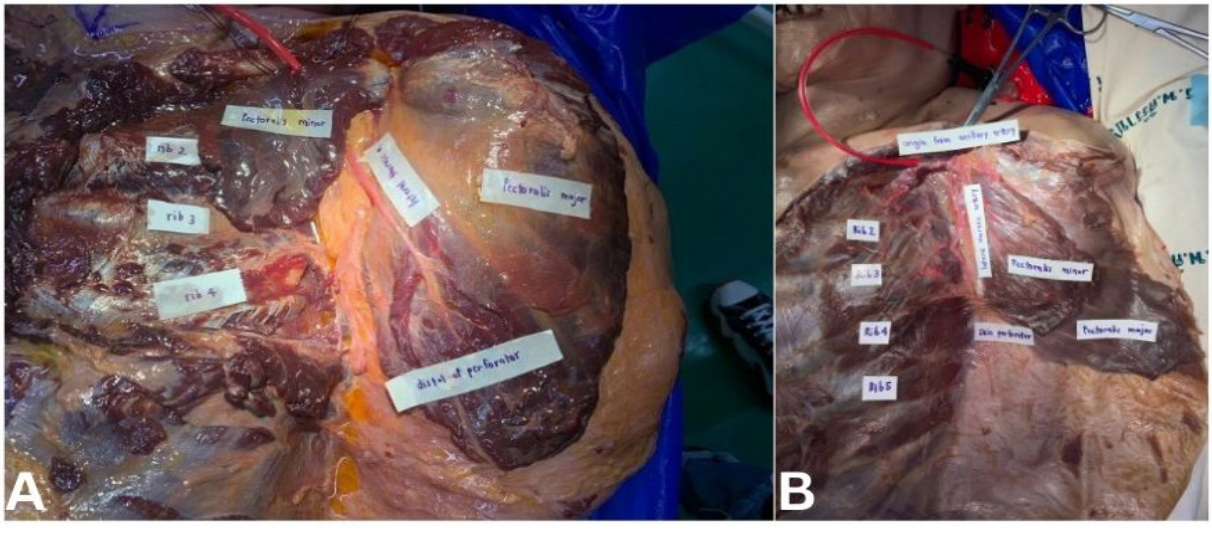


Fig 3. Cadaveric dissection of the (A) left lateral thoracic artery (LTA) and (B) lateral thoracic perforators of the skin between the 3rd to 5th ribs.

TABLE 3. Correlation between lateral thoracic artery and perforators of thoracic CTA and soft cadavers.

Variable	Thoracic CTA		Cadavers		*p*-value
	Right side	Left side	Right sode	Left side	
LTA type by origin					
Axillary	31 (77.5)	28 (70.0)	8 (72.7)	6 (60.0)	0.391
Thoracodorsal	0 (0)	1 (2.5)	1 (9.1)	2 (20.0)	
Subscapular	9 (22.5)	11 (27.5)	2 (18.2)	2 (20.0)	
Length from origin (mm.) (Mean ± SD)	91.6 ± 20.8	87.5 ± 20.4	125.7 ± 26.0	108.2 ± 23.0	**0.010**
Diameter (mm.) (Mean ± SD)	2.1 ± 0.4	2.0 ± 0.4	2.3 ± 0.4	2.2 ± 0.2	0.200
Distance from lateral border of pectoralis major (mm.) (Mean ± SD)	6.1 ± 0.8	4.5 ± 0.5	3.4 ± 0.7	4.1 ± 0.7	0.176
Distance from anterior border of latissimus dorsi (mm.) (Mean ± SD)	36.5 ± 13.4	35.5 ± 13.0	38.6 ± 6.6	37.1 ± 6.3	0.738
Distance from acromioclavicular joint (mm.) (Mean ± SD)	139.8 ± 23.4	133.5 ± 22.0	170.6 ± 17.7	165.9 ± 17.1	**0.008**
Number of perforators (Mean ± SD)	1.4 ± 0.7	1.2 ± 0.4	2.0 ± 0.8	2.4 ± 1.0	**0.005**
Number of lymph nodes (Mean ±SD)	0.8 ± 0.8	0.8 ± 1.0	1.5 ± 1.2	0.9 ± 0.8	0.754

All specified lengths, diameters, and distances are in millimeters (mm). Data is expressed as mean ± standard deviation or n (%).
Abbreviations: CTA, Computed Tomography Angiography; LTA, Lateral Thoracic Artery.

LTAs originated most frequently from the axillary artery (73.8% in thoracic CTAs and 66.4% in cadavers), followed by the thoracodorsal arteries (25.0% in thoracic CTAs and 19.1% in cadavers), and least frequently from the subscapular artery (1.3% in thoracic CTAs and 14.6% in cadavers). LTAs that originated from axillary arteries were more common in right LTAs, while those originating from the subscapular and thoracodorsal arteries were more common on the left side. There were no significant differences in LTA type by anatomical location, arterial diameter, distance from the pectoralis major and latissimus dorsi, or the number of proximal LNs across groups.

DISCUSSION

The authors assessed the anatomical characteristics, dimensions, and landmarks of the LTA and its perforators through thoracic CTAs and cadaveric dissection. They found that cadavers had a significantly greater LTA length from origin, distance from the acromioclavicular joint, and number of cutaneous perforators. LTAs most frequently originated from the axillary artery, followed by the subscapular and thoracodorsal arteries, respectively. To the authors' knowledge, no prior publications have reported on the diameter and lengths of cutaneous perforators of the LTA within the 4th intercostal space.

The lateral thoracic region flap, located between the pectoralis major and latissimus dorsi muscles, is highly vascularized with multiple cutaneous perforators that supply the skin. Its hairlessness and favorable length-to-width ratio make it highly versatile and convenient for mobilizing to adjacent wounds or defects for closure or reconstruction. This versatility supports the shift from conventional musculocutaneous or myocutaneous flaps to perforator flaps as plastic surgeons' knowledge regarding microsurgical methods and vascularization improves.[20] Perforators enable the harvesting of various thin flaps from the same region while preserving the source vessels, transforming traditional donor sites into universal donor sites. Flaps that can be harvested from the lateral thoracic region include the thoracodorsal artery perforator (TDAP) flap, LICAP flap, and LTAP flap.[21,22]

The researchers found that, on average, 73.8% of LTAs from thoracic CTAs and 66.4% from cadavers originated from the axillary artery. A smaller percentage variably originated from the subscapular artery or thoracodorsal artery, as noted previously. The LTA diameters averaged 2.1 and 2.3 millimeters, with lengths of 89.6 and 117.0 millimeters for thoracic CTAs and cadavers, respectively. This study confirmed that the LTA runs parallel to the lateral border of the pectoralis major and anterior border of the latissimus dorsi, supplying the pectoral muscles and serratus anterior through muscular branches, and providing blood to the skin between the 3rd-6th intercostal spaces of the lateral thoracic region through direct cutaneous perforators.

One study used magnetic resonance imaging (MRI) to confirm the LTA's anatomical location and enumerate its direct cutaneous perforators in the lateral thoracic region. It found that 94.3% of LTAP flaps were supplied by an average of 2 perforators located roughly 172.2 millimeters from the axillary artery.[13] Similar findings were noted in the study's cadaveric dissections, with 1-2 perforators observed between the 3rd-6th intercostal spaces. These cutaneous perforators were especially prevalent (up to 100%) between the 4th-5th intercostal spaces.

The researchers also confirmed that LTAP flaps contain at least one LN that can be transferred for treating lymphedema. Seventy percent of these LNs were found 10 millimeters proximal to the LTA, particularly within the 3rd-6th intercostal spaces, similar to the cutaneous perforators. One limitation of the LTAP flap is the small size of its venae comitantes, which often provides inadequate venous drainage. As a result, the lateral thoracic vein should typically be included when harvesting the flap. However, dissection of the pedicle can be challenging because it is often embedded in a thick layer of fat, and the lateral thoracic vein can follow a different course from the artery. Additionally, the lateral thoracic pedicle is generally shorter and smaller than the thoracodorsal vessels.

Limitations

This study had some limitations. The first was its exclusion of perforasome dimensions. LTA perforators narrower than 0.6 millimeters could not be accurately identified from thoracic CTA imaging, which may have influenced the recorded lengths and number of perforators for thoracic CTAs. Differences in positions during imaging and cadaveric dissection could potentially result in discrepancies of the data, especially in LTA length. Additionally, the narrow diameter prevented cannulation and ink injection for photographic contrast in cadavers. The second limitation was that LN counts were performed by eye. More accurate enumerations would require stereomicroscopic investigation.

Recommendations and future directions

LTAP dimensions for surgical removal are routinely oriented vertically and are elliptical in shape (10 × 5 centimeters).[16] It is recommended that the pointed ellipse be positioned between the anterior and posterior axillary lines, 20 millimeters away from the axillary neurovascular bundle.[16,23] An incision is typically made at the anterior axillary line, and the flap is harvested through dissection in the suprafascial plane between the lateral border of pectoralis minor and the second intercostal brachial nerve.[23] Based on our findings, the researchers recommend harvesting LTAP flaps between the lateral border of the pectoralis major and the anterior border of the latissimus dorsi, specifically above the 3rd-6th ribs. This approach avoids damaging the LTA while including perforators and proximal LNs of the lateral thoracic region. Incisions between the 4th-5th intercostal spaces should be executed cautiously to prevent damaging any structures within the lateral thoracic region. The researchers are also looking forward to using this flap as a vascularized lymphatic flap for treating lymphedema.[24]

CONCLUSION

LTAP flaps are an alternative, conservative approach to plastic reconstruction and microsurgery. This study determined the anatomical characteristics, dimensions, and landmarks of the LTA and its perforators through thoracic CTAs and cadaveric dissection. The authors confirmed the anatomical location, characteristics, and dimensions of the LTA and provided insights into the nature of its direct cutaneous perforators. Equipping surgeons and medical practitioners with this knowledge is crucial for surgical planning, minimizing damage to the LTA, and including perforators and proximal LNs of the lateral thoracic region. The researchers recommend harvesting LTAP flaps between the lateral border of the pectoralis major and the anterior border of the latissimus dorsi, specifically above the 3rd-6th ribs.

ACKNOWLEDGEMENT

None

DECLARATION

Grants and Funding Information

This research is funded by the Siriraj Research Development Fund, grant number R016631025.

Conflicts of Interest

All authors declare no personal or professional conflicts of interest related to any aspect of this study.

Author Contributions

Conceptualization and methodology, S.T., A.C.; Investigation, P.P., J.W., P.P.; Formal analysis, N.T.; Visualization and writing – original draft, P.P., S.T.; Writing – review and editing, S.T., M.Y., B.K.; Funding acquisition, S.T.; Supervision, A.C. All authors have read and agreed to the final version of the manuscript.

Use of Artificial Intelligence

This study did not utilize any artificial intelligence.

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