นิพนธ์ต้นฉบับ

Cadaveric study of the lower portion of the serratus anterior muscle.

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Background : *The lower serratus an terior muscle free flap has not gained wide acceptance for reconstructions. This may be due to concerns about uncertainty of the vascular supply and the effects on scapular function.*

Objective : *To study variations in the anatomy of the lower portion of the serratus anterior muscle.*

Setting : *Department of Anatomy, Faculty of Medicine, Chulalongkorn University.*

Research design : *Descriptive statistics*

Material : *Sixty two embalmed cadaver dissections of serratus anterior muscle.*

Methods : *Measurements were taken in situ. Statistical analysis was done on an Excel 5 spreadesheet in Microsoft Windows 95 software.*

Results : *The lower four to six slips of the serratus anterior muscle are supplied by one to three branches from the thoracodorsal artery, the serratus branches. Three vascular patterns were identified : type I with one branch (53 percent), type II with two branches (39 percent), and type III with three branches (8 percent). The mean dimensions of the lower serratus anterior flap were 14.9±1.5 X 12.3±1.5 cm (range 12.0 X 9.5 cm to 16.0 X 15.7cm). The mean pedicle length was 8.3±1.3 cm (range 5.2 to 11.5 cm). A crossing point landmark has been identified*

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to facilitate flap dissection. This landmark marks the junction of the long thoracic nerve and the dominant serratus branch. This landmark can be found at the superior border of the sixth or seventh rib.

Conclusion : *The lower serratus anterior flap may be used for reconstruction of small to moderate-sized defects because of its flat, broad dimensions and long vascular pedicle.*

Key words : *Serratus anterior , Flap , Anatomy.*

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มนตกานต์ ตันสถิตย์, ธันวา ตันสถิตย์. การศึกษากายวิภาคของกล้ามเนื้อเซอร์ราตัส แอนทีเรีย ส่วนล่างในศพดอง. จุฬาลงกรณ์เวชสาร 2541 มิ.ย; 42(6): 441-53

เหตุผลของการทำวิจัย : *ส่วนล่างของกล้ามเนื้อ serratus anterior ยังไม่ได้รับการยอมรับอย่างกว้างขวางในการใช้เป็นเนื้อเยื่อปลูกถ่าย เพื่อแก้ไขความบกพร่องของร่างกาย อันเนื่องมาจากความไม่แน่ชัดในลักษณะของหลอดเลือดที่มาเลี้ยงกล้ามเนื้อ และผลของหน้าที่การทำงานที่อาจสูญเสียไปของกล้ามเนื้อ*

เป้าหมาย : *เพื่อศึกษาลักษณะความผันแปรต่าง ๆ ทางกายวิภาคศาสตร์โดยละเอียดในแง่มุมที่จะใช้ในการผ่าตัดของกล้ามเนื้อ serratus anterior โดยเฉพาะในส่วนล่างของกล้ามเนื้อ*

สถานที่ : *ภาควิชากายวิภาคศาสตร์ คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย*

รูปแบบการวิจัย : *การศึกษาวิจัยเชิงบรรยาย*

ปัจจัยในการวิจัย : *กล้ามเนื้อ serratus anterior จำนวน 62 มัดจากศพที่ผ่านกระบวนการเก็บรักษา 31 ศพ*

วิธีการทำวิจัย : *ชำแหละแล้ววัดขนาดของององค์ประกอบต่าง ๆ ของกล้ามเนื้อ*

ผลการวิจัย : *กล้ามเนื้อ serratus anterior ในส่วนล่างจำนวน 4-6 แถบกล้ามเนื้อได้รับเลือดมาเลี้ยงโดยแขนงของหลอดเลือดแดง thoracodorsal 1-3 แขนงที่เรียกว่าแขนง serratus ความแตกต่าง 3 แบบที่พบได้คือ*

แบบที่ 1 มี 1 แขนง (53 เปอร์เซนต์)
แบบที่ 2 มี 2 แขนง (39 เปอร์เซนต์)
แบบที่ 3 มี 3 แขนง (8 เปอร์เซนต์)

ค่าเฉลี่ยของขนาดของแผ่นกล้ามเนื้อ serratus anterior ส่วนล่างที่สามารถตัดออกไปใช้ได้ คือ 14.9±1.5 X 12.3±1.5 ซม. (ตั้งแต่ 12.0 X 9.5 ซม. จนถึง 16.0 X 15.7 ซม.) ความยาวของขั้วที่เป็นก้านหลอดเลือดทอดไปสู่กล้ามเนื้อคือ 8.3 ±1.3 ซม. (ตั้งแต่ 5.2 ถึง 11.5 ซม.) ได้มีการกำหนดจุดตัดกันที่เป็นตำแหน่งหลัก เพื่อใช้เป็นจุดสังเกตช่วยให้การผ่าตัดเลาะแผ่นกล้ามเนื้อไปใช้เป็นไปได้ด้วย

*ความสะดวกรวดเร็วและแม่นยำ จุดสังเกตนี้เป็นตำแหน่งที่เส้นประสาท **long thoracic** ทอดทับกับแขนงหลัก **serratus** ของหลอดเลือดแดง **thoracodorsal** จุดตัดกันนี้สามารถพบได้โดยง่ายที่บริเวณผิวกล้ามเนื้อในระดับเดียวกับขอบบนของซี่โครงซี่ที่ 6 หรือ 7*

สรุป : *กล้ามเนื้อ **serratus anterior** ส่วนล่างอาจเลาะไปใช้ได้ในการผ่าตัดแก้ไขความบกพร่องที่มีขนาดเล็กและขนาดกลางจากลักษณะที่แบนกว้างและมีก้านหลอดเลือดที่ยาวของกล้ามเนื้อส่วนนี้*

The lower serratus anterior muscle was first transferred as a free flap by Takayanagi and Tsukie in 1982.[1] The muscle was taken with the latissimus dorsi muscle as a composite free flap.[2-4] The serratus anterior was transferred as an osteocutaneous free flap[7-9] or fascia flaps.[10] It has also been used as a pedicle flap in the reconstruction of thoracic[10-13] and head and neck[14-16] defects. Whitney et al have described 100 clinical cases of free-flap transfer with little morbidity and few complications.[17] Despite its documented clinical usefulness,[18] the lower serratus anterior muscle free flap has not gained wide acceptance. This may be due to concerns about the effect on scapular function[19] and uncertainty about effects on the vascular supply.

According to standard textbooks of anatomy, the serratus anterior muscle is segmented into slips originating anteriorly from ribs 1 to 10 and inserting along the medial border of the scapula. The serratus anterior muscle is attached to the costal (ventral) surface of the scapula from the superior to the inferior angles.[20-24] In addition, the levator scapulae and the rhomboideus muscles attach to the dorsal surface of the scapula. (Figure 1)

The serratus anterior consists of two portions; The upper portion arises from the superior angle and the vertebral border of the scapula and extends to the upper five ribs. The lower portion contains the remaining four to six slips, originating from ribs 6 to

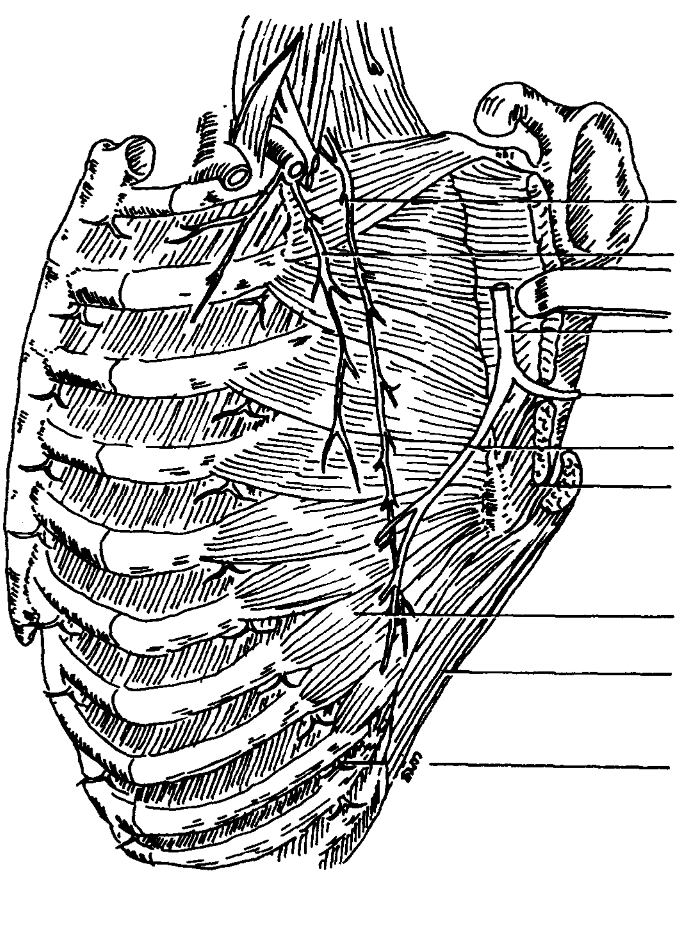

Figure 1. Anatomy of the lower serratus anterior muscle.

10 and inserting on the inferior angle of the scapula. It is this lower portion that can be transferred as a free flap , leaving the upper portion intact. The serratus anterior muscle flap receives its blood supply superiorly from the long thoracic artery in the front and inferiorly form branches of the thoracodorsal artery in the back of the muscle. The long thoracic nerve supplies the serratus anterior muscle , ramifies in company with the lateral thoracic artery superiorly and with the serratus branches of the thoracodorsal artery inferiorly. The purpose of this study is to document flap dimensions and pedicle length and describe anatomical variations of clinical significance.

Materials and methods

Sixty two dissections were performed on 31 embalmed cadavers aged 33 to 91 years (average 70±15.8 yr.) Thirteen were male and 18 female. Heights were between 143 and 170 cm (average 159.4±6.7 cm), weights were 45 to 80 kg. (average 62.9±8.3 kg). Bilateral comparative dissections were performed in all cadavers. Measurements were taken in situ with the arm abducted to 90 degrees using vernier calipers. The effective pedicle length for the lower serratus anterior muscle flap was measured from the circumflex scapular artery to the point of entry of the dominant first serratus branch into the muscle fascia. The external vessel diameter was recorded for the thoracodorsal vessels (both artery and vein) and each serratus branch. The distance between each serratus branch was taken as a measurement. Flap width was measured from the point of entry of the dominant serratus branch to the last slip of muscle along the midaxillary line. Flap length was measured from the most anterior rib of origin to the inferior angle of the scapula posteriorly (Figure 2). The relationship between the long thoracic nerve and the dominant serratus branch was studied and the distance between them was recorded. Then branch of the nerve supplied the flap was dissected and the main trunk left to preserve the innervation of the remaining part of the muscle. Statistical analysis was done using an Excel 5 spreadesheet with Microsoft Windows 95 software operating system.

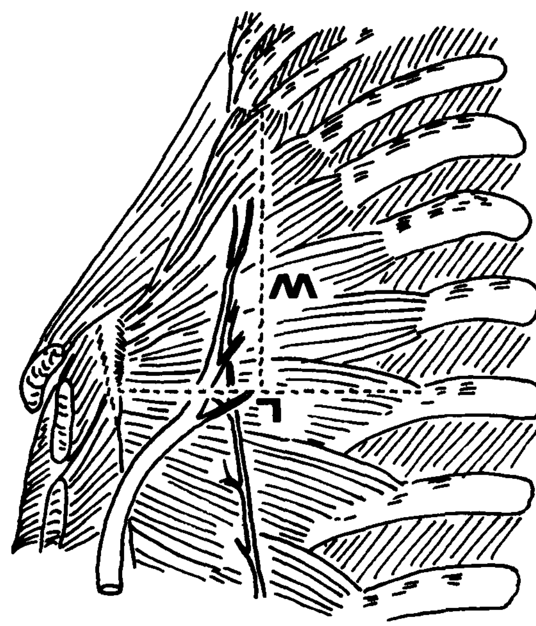

Figure 2. รูปการวัด serratus anterior flap.

Results

The Vascular Anatomy

In all dissections , the lower serratus anterior muscle received its arterial supply from branches of the thoracodorsal artery. Three branching patterns were found

: type I-one branch (53 percent) (Figure.3a)

: type II-two branches (39 percent) (Figure.3b)

: type III-three branches (8 percent) (Figure.3c)

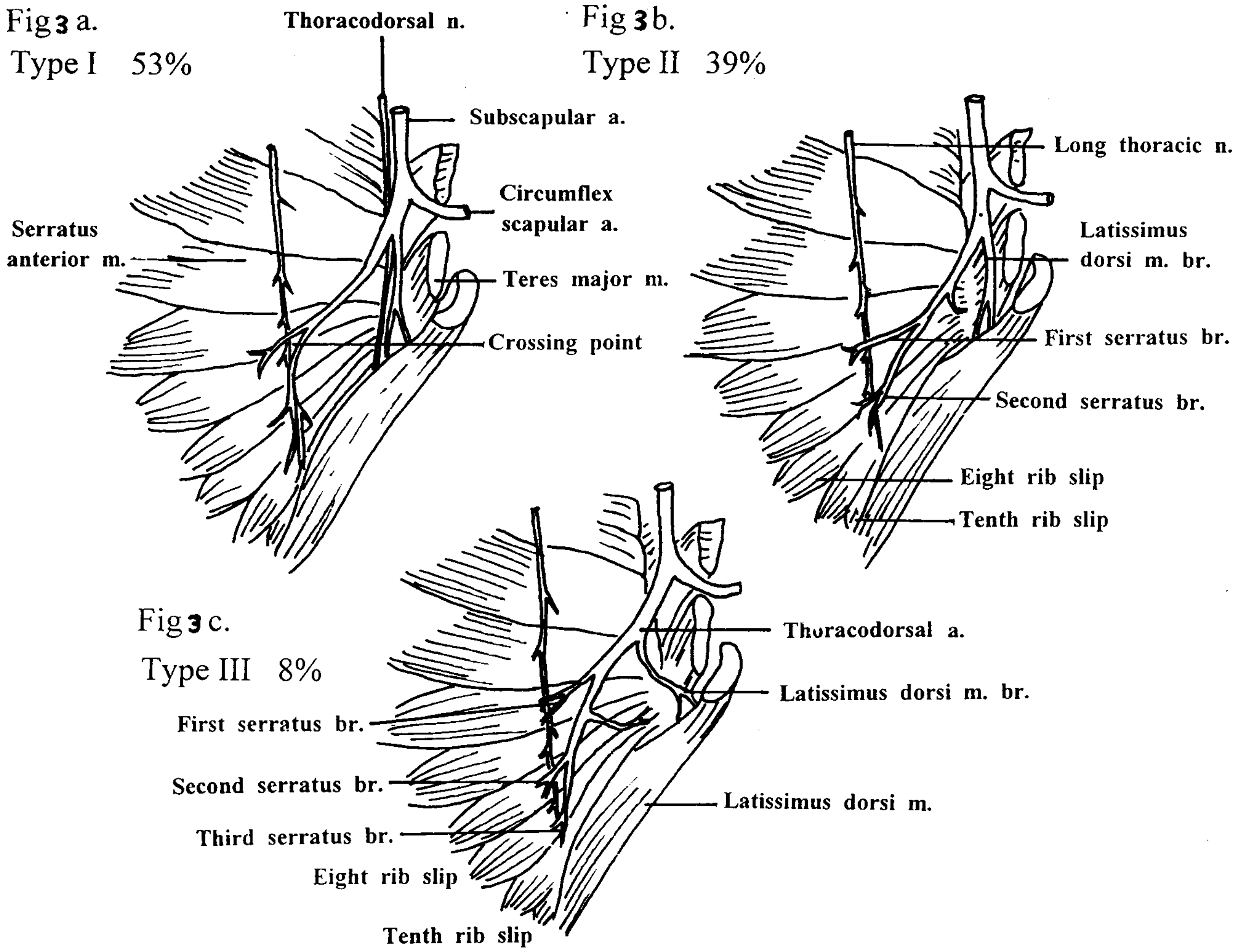

Figure 3. Three branching patterns of the serratus branches of the thoracodorsal artery. **Type I** arterial pattern. There is a single vessel from the thoracodorsal artery supplying the lower serratus muscle. **Type II** arterial pattern. The lower serratus muscle is supplied by two branches from the thoracodorsal artery. The dominant branch enters the muscle where it crosses the long thoracic nerve. **Type III** artrial pattern. The lower serratus muscle is supplied by three branches from the thoracodorsal artery.

An asymmetrical number of branches was noted in 10 of the 31 bilateral dissections (32%). The mean effective pedicle length was 8.3±1.3. cm (range 5.2 to 11.5 cm). External diameters of the thoracodorsal artery and vein measured 3.5±0.7 mm and 4.4±1.1 mm (Table 1) and the serratus branches averaged (both artery and vein) 2.3±0.6 mm and 2.3±0.8 mm in diameter (Table 2). The external diameter of each serratus branch was 2.4±0.7 mm , 2.0±0.6 mm and 2.2±0.6 mm for the artery and 2.4±0.8 mm , 2.2±0.8 mm and 2.0±0.7 mm for the venae comitantes of the arterial branch (Table 2). The distance between the first and the second serratus branches was 2.0±1.5 cm and 1.8±0.4 cm for the distance between the second to the third. Mean of these distances between the serratus branches was 2.0±1.4 cm (Table 3). The lateral thoracic

Table 1. Measurement of the vascular anatomy.

The mean effective pedicle length	8.3 ± 1.3 cm (range 5.2 to 11.5 cm).
External diameter of the thoracodorsal artery	3.5 ± 0.7 mm
External diameter of the thoracodorsal vein	4.4 ± 1.1 mm

Table 2. The external diameter of each serratus branch.

Artery	
• first branch	2.4 ± 0.7 mm
• second branch	2.0 ± 0.6 mm
• third branch	2.2 ± 0.6 mm
Venae comitantes of the arterial branch	
• first branch	2.4 ± 0.8 mm
• second branch	2.2 ± 0.8 mm
• third branch	2.0 ± 0.7 mm
The average external diameter of the serratus branches	
• artery	2.3 ± 0.6 mm
• vein	2.3 ± 0.8 mm

Table 3. The distance between each serratus branch.

• the first and the second serratus branch	2.0 ± 1.5 cm
• the second and the third serratus branch	1.8 ± 0.4 cm
Mean of these distances between the serratus branches	2.0 ± 1.4 cm

the lower serratus anterior muscle (37.1%). Collateralization between the lateral thoracic and serrratus branches was noted in 18 of the 62 dissections (27%).

In one dissection, there was no lateral thoracic artery. On one side of another cadaver, the lateral thoracic artery arose from the subscapular artery (in common trunk with the thoracodorsal artery).

Our examinations revealed that the venous drainage paralleled the arterial supply. Venae comitantes accompanied the serratus arterial branches. In all cases, the venae comitantes of the serratus branches united to form a single thoracodorsal vein. The venae comitantes were approximately the same size as the arterial serratus branches.

The Muscular Anatomy

The entire serratus anterior muscle has 7 to 10 slips (mean 8.6±0.9 slips) in the following distribution : 7 slips—5 percent; 8 slips—48 percent; 9 slips—32 percent; and 10 slips—15 percent. The number of slips that would ideally be harvested in each case was determined by the point of entry into the muscle fascia of the dominant serratus branch of the thoracodorsal artery. This landmark was termed the crossing point and was a consistent landmark where the lateral thoracic nerve and the dominant serratus branch crossed and arborized, usually at the sixth or seventh slip on the sixth or seventh rib. A smaller flap could be obtained with additional dissection of the vascular pedicle form the surface of the muscle ; however, because of the multitude of arterial branches from the main trunk supplying the muscle, this dissection was difficult and significantly enhanced the risk of trauma to the vascular pedicle. Taking a larger flap would leave a small muscle in situ, but can appreciably increase the overall size of the flap. The anterior portions of the slips could be separated without compromising the blood supply, but the demarcation between slips becomes less distinct posteriorly, and sharp dissection was required. The lower slip of the flap inserted onto rib 9 or 10 and was often diminutive in nature. The lower serratus anterior muscle slips originated from the costal attachments of the rib cage along ribs 6 through 10. A broad attachment from each rib of about 3 to 4 cm was noted, requiring sharp dissection off the periosteum. Perforators from the intercostal vessels also were noted, especially at the anterior border. Interdigitations with the external oblique muscle were present. The lower slips coalesced into a single bundle attachment at the tip of the scapula. No variations were noted in either origin or insertion. No muscle attachments were noted to other muscles. A distinct deep avascular plane allowed easy dissection of the flap between the rib origin and the scapular insertion. The mean dimensions of the lower serratus anterior flap were 14.9±1.5 X 12.3±1.5 cm (range 12.0 X 9.5 cm to 16.0 X 15.7 cm). The mean trapezoid-shaped flap area was 184± 33 cm^2 (range 114 to 251 cm^2). The number of lower slips that could be harvested with the flap ranged from three to six, and in 77.5 percent of cases, four to five slips could be harvested. The muscle mass remaining is 52.3±6.3 percent. Of interest was the number of slips remaining after removal of the lower serratus muscle. In 85 percent, five or more upper slips remained in situ ; however, in 15 percent, only four slips remained. This may have clinical significance in terms of scapular stability.

The Long Thoracic Nerve

The long thoracic nerve is unique in that it runs superficially to the muscle over its entire course (Mean 11.3±1.5 cm). This course was remarkably consistent. It lay anteromedially and ran obliquely from the lateral thoracic artery to the thoracodorsal vascular pedicle to intersect with the dominant serratus branch artery at the crossing point. At this point, in 83.9 percent of the dissections, the nerve passed deep to the vascular pedicle and, in 16.1 percent, split around the pedicle and dominant branch. Along its course the nerve divided into small branches parallel to the main trunk for a few centimeters (Mean 2.3±1.0 cm) prior to diverging at right angles and entering the superior aspect of individual muscle slips. Distally, upon intersection with the vascular pedicle, the long thoracic nerve disperses its remaining fascicles in a crow's foot pattern to innervate the remaining lower slips. The distance between the crow's foot of nerves to the dominant serratus branch was 2.1±1.6 cm. A nerve pedicle could be included if a functional graft were required, as described by Whitney et al.[17] and Brody et al. [18] With additional dissection, the fascicles may be teased apart (93.5 percent) and a longer graft was obtained while still preserving the innervation to the remaining muscle.

Discussion

This study confirms previous reports on the muscle anatomy, vascular supply, and innervation of the lower serratus anterior muscle. Several important anatomical variations and observations were noted that could have clinical significance. The crossing point was a consistent and reliable landmark. It indicates the point of arborization of the long thoracic nerve and marks the point of convergence of the long thoracic nerve and dominant serratus branch. It also establishes the location for separation between the upper and lower serratus in flap dissection. In all cases, the lower serratus muscle could be harvested based on serratus branches from the thoracodorsal artery. Variability in the frequency and number of branches has been noted in the past : Bartlett et al. [25] in 50 cadaver dissections reported 54 percent type I, 44 percent type II, and 2 percent type III. Rowsell et al. [26] in 100 cadaver dissections noted 72 percent type I, 24 percent type II, and 2 percent type III. One cadaver had four branches. Van Thienen and Deraemaecker [27] in 32 cadavers noted 75 percent type I and 25 percent type II. This variability may be explained by the dissection technique. At least four cases have been described in the literature in which the serratus branch originated from either the subscapular artery or the axillary artery. [27-30] Our data found a case without the lateral thoracic artery from one side and in another case in which this artery arose from the subscapular artery. Depending on the entry point into the lower serratus muscle, this may affect the effective pedicle length and the dimension of flap. Whitney et al. [17] in 100 clinical cases found that despite variability, the serratus muscle could always be harvested. Fisher et al. [31] noted the absolute presence of serratus branches in all 775 clinical cases observed at the time of mastectomy. The anatomical variation in vascular supply of the lower serratus muscle is not a significant problem in harvesting this muscle in the flap reconstruction. Recently, an endoscopic technique for free flap harvesting has been developed without the conventional pattern of scarring. [32] Thus this flap can be used in every patients whenever it is needed.

The difference in every parameter between the right side and the left side was not significant except for the length of the flap (Table 4). On the right side , the length of the flap from the most anterior part of the muscle to the inferior angle of the scapula is significantly longer than the left side.

Table 4. The difference between the variable parameter of the right side and the left side.

The variable parameter	P value
The effective pedicle length (thoracodorsal artery)	0.81
External diameter of the thoracodorsal artery	0.56
External diameter of the thoracodorsal vein	0.35
External diameter of each serratus branch	
• first branch (artery and vein)	0.47 and 0.57
• second branch (artery and vein)	1.00 and 0.24
• third branch (artery and vein)	0.57 and 0.20
Flap width	0.41
Flap length	0.00*
Dimension of the flap	0.20

Paired T test was performed for each variable.

* A P - value less than 0.05 was considered significant. ($\alpha = 0.05$)

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