The Anatomy of the Thoracodorsal Artery in Perforator Flap for Resurfacing Shallow Defect

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Objective: *To systematically determine the location and number of cutaneous perforators greater than 0.5 mm in diameter of the lateral branch of the thoracodorsal artery perforator flap for resurfacing shallow defect.*
Material and Method: *Sixty dissections of the thoracodorsal arterial system were carried out in 30 preserved cadavers. The location and number of cutaneous perforators greater than 0.5 mm in diameter of the lateral branch of the thoracodorsal artery perforator flap were studied and measured.*
Results: *Seventy-six perforators were found in 60 flaps (1.3 perforators per flap). The first perforator was exited in all dissections. It emerged from the latissimus dorsi muscle 9.8 cm below the dome of the axilla. In 21.67% of the cases, the second perforator of the thoracodorsal artery arose 3.4 cm distal to the origin of the first perforator. The third perforator was found in 5% of dissections, and originated 3.0 cm away from the origin of the second perforator. In addition, most perforators penetrated the muscle within 7.0-14.0 cm below the dome of the axilla.*
Conclusion: *The center of the flap designed should be placed between 7 to 14 cm from the dome of the axilla.*

Keywords: *Thoracodorsal artery, Perforator flap, Resurfacing shallow defect*

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The latissimus dorsi musculocutaneous flap is one of the most reliable living tissues in reconstructive surgery[1]. However, the flap includes a large muscle portion, resulting in significant functional impairment[2,3]. Additionally, thickness of this flap is not suitable for resurfacing the shallow defect of a distal limb[4]. Perforator based flaps from the back can be made thin for aesthetic, functional refinement and useful for resurfacing defect[4,5]. The need for thin flap coverage has increased, especially for contouring or covering of shallow defects caused by crushing or degloving injuries, the release of contracted burn scars, and wide resections of the skin cancer[5]. Since Angrigiani[1] is the first who described the concept of the thoracodorsal artery perforator (TDAP) flap, the harvesting technique of the latissimus dorsi musculocutaneous flap has been modified to exclude the muscle portion and to achieve only the cutaneous part, supplied by a single perforator of the thoracodorsal artery[4]. Later on, several other reports concerning the use of this flap have been published[2,5-12]. The thoracodorsal artery perforator flap has attracted great interest because its distinct advantages including a long donor vessel that can reach a recipient vessel far from traumatized or irradiated defects, provides a flap of suitable thickness for resurfacing the shallow defect of a distal limb, the function in the latissimus dorsi muscle is preserved, and the donor region is hidden well in clothes. The main disadvantage of the TDAP flap is very troublesome because blood vessels are with varying diameters and locations, requiring prolonged surgery[1,4,10,11]. The specific pattern, size, and location of the perforating vessels are important in the wide and varied recon-

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structive applications of this flap[13]. The pedicle and perforators of the lateral branch are generally locate along the lateral border of the muscle which are more reliably determined, allows for a safe and rapid dissection[5]. For these reasons, the authors focused only on the cutaneous perforators of the lateral branch of thoracodorsal artery, but details of the cutaneous perforator pattern of the lateral branch of the TDAP flap has remained unclear, and a few cases have been reported to guide the harvest of the TDAP flap. In addition, systematic collection of the data related to the thoracodorsal artery perforator flap has not been done. Therefore, the presented dissection was performed to clarify the anatomy of the cutaneous perforating vessels of the lateral branch of the thoracodorsal artery.

Material and Method

Sixty dissections of the thoracodorsal arterial system were made in 30 preserved cadavers. To facilitate dissection, each cadaver was placed in the supine position with the shoulder abducted at 90 degrees. In each case, the area to be dissected was approached through an axillary incision or by means of further reflection of the midline incision commonly employed at autopsy. The thoracodorsal artery and thoracodorsal nerve were identified. The perforating vessels of the lateral branch of the thoracodorsal artery with a diameter of 0.5 mm or more were dissected. The following anatomical features were studied and measured, (1) the numbers (greater than 0.5 mm in diameter) of the perforator of the lateral branch of the thoracodorsal artery; (2) the location (from the dome of the axilla to the penetrating site of the muscle), diameters (at its origin), lengths (distance from the origin to the penetrating site of the muscle), and pattern of the perforators of the lateral branch of the thoracodorsal artery. The photographs and dissection notes were analyzed.

Statistical analysis was undertaken with SPSS version 9.0.The data of measurements were analyzed by descriptive statistics as means, standard deviation, ranges, and percentages.

Results

The thoracodorsal artery arose from the subscapular artery and entered the deep surface of the latissimus dorsi muscle. The average length of the thoracodorsal artery, from the axillary artery to the inner surface of the muscle where the perforator disappeared, was 16.2 $\pm$ 2.0 cm (range: 12.0-21.8 cm) (mean $\pm$ SD) and the average diameter of the thoracodorsal artery at its bifurcation was 3.0 $\pm$ 0.8 mm (range: 2.0-5.0 mm).

The location of the bifurcation on the deep surface of the latissimus dorsi muscle, number and percent of the bifurcation each location are reported in Table 1. In the majority of the bifurcation (61.67%), located 1.8 $\pm$ 0.9 cm (range: 0.5-3.5 cm) distal to the tip of the scapula. In addition, the location of the trunk was 5.0 $\pm$ 1.5 cm (range: 2.0-9.0 cm) below the dome of the axilla. At this point, the trunk always bifurcated into a horizontal branch and a lateral branch.

The thoracodorsal artery divided into medial and lateral branches. The medial or the horizontal branch ran horizontally across the upper muscle. The lateral or the descending branch ran parallel to the lateral edge of the muscle toward the iliac crest. The mean distance, diameter and length of the lateral and medial branch of the thoracodorsal artery are shown in Table 2.

Seventy-six perforators larger than 0.5 mm were found in 60 flaps. There was an average of 1.3 perforators (range: 1-3 perforators). The first perforator of the lateral branch was found in 100% of dissections. The location of the first perforator that measured from the dome of the axilla to its origin was 7.8 cm and 1.7 cm from the lateral border of the muscle. In 21.7% of dissections (13 in 60 flaps), the second perforator arose 3.4 cm distal to the origin of the first perforator. The third perforator was found in 5% of dissections (3 in 60 flaps), originated 3.0 cm distal to the origin of the second perforator. The mean of the diameter, length, and piecing point to the muscle (from the dome of the axilla) for each perforator are demonstrated in Table 3.

In addition, average distances of the perforators from the lateral branch of the thoracodorsal artery

Table 1. The location related to the tip of the scapula and number of the bifurcation of the thoracodorsal artery

Location	Distance (cm) (mean $\pm$ SD)	Number	
Proximal to the tip of the scapula	1.9 $\pm$ 0.7 (range: 1.0-3.5)	20	(33.3%)
Distal to the tip of the scapula	1.8 $\pm$ 0.9 (range: 0.5-3.5)	37	(61.7%)
The same level with the tip of the scapula		3	(5.0%)
Total		60	(100%)

Table 2. The distance from free borders, diameter, and length of the lateral and medial branches of the thoracodorsal artery

Distance from free borders to arterial branches (cm)		Diameter of the origin at the bifurcation (mm)		Length of pedicle from its origin (cm)	
A	B	LB	MB	LB	MB
1.7 ± 0.6	2.2 ± 0.6	2.6 ± 0.4	2.0 ± 0.5	8.9 ± 1.9	2.9 ± 0.8
(0.5-3.5)	(0.5-4.0)	(1.9-3.7)	(1.2-3.5)	(5.5-15.5)	(1.3-5.5)

Abbreviations: A, distance from lateral border of muscle to lateral branch; B, distance from superior border of muscle to medial branch; MB, medial branch; LB, lateral branch
Data were presented with mean ± SD (range)

Table 3. Mean distance, diameter, and length of each perforator of the lateral branch

Perforator	Distance (cm)	Diameter (mm)*	Length (cm)**	Piece to muscle (cm)***
1st +	7.8 ± 2.6 (2.0-15.0)	1.3 ± 0.3 (0.7-2.0)	3.0 ± 1.8 (0.7-11.5)	9.8 ± 2.6 (4.1-14.8)
2nd + +	3.4 ± 2.1 (1.2-8.5)	1.2 ± 0.2 (1.0-1.6)	3.3 ± 2.2 (1.0-8.5)	11.6 ± 2.0 (8.0-14.5)
3rd + + +	3.0 ± 1.6 (1.2-4.0)	1.0 ± 5.8 (1.0-1.1)	2.4 ± 0.5 (2.0-3.0)	12.1 ± 1.9 (10.3-14.0)

Abbreviations: +, distance from the dome of the axilla to the origin of 1st perforator; + +, distance from the origin of the 1st perforator to 2nd perforator; + + +, distance from the origin of the 2nd perforator to 3rd perforator; * , at its origin; **, the origin to piece to muscle; ***, from the dome of the axilla
Data were presented with mean ± SD (range)

Table 4. The patterns of the perforators and the muscular branches of the lateral branch

Pattern	Number		Number	Percent (%)
	Perforator	Muscular		
I	1	1	23	38.3
II	1	2	18	30.0
III	1	3	5	8.3
IV	1	4	1	1.7
V	2	1	3	5.0
VI	2	2	5	8.3
VII	2	3	2	3.3
VIII	3	1	2	3.3
IX	3	4	1	1.7
Total			60	100.0

from the dome of the axilla to the penetrating site to the muscle, were 10.2 ± 2.6 cm (range: 4.1-14.8 cm) (Fig. 1, 2). Most of the perforators penetrated the muscle at 7 to 14 cm distal to the dome of the axilla.

In addition, the pattern of the perforators and the muscular branches of the lateral branch were classified into nine patterns (Table 4). Pattern I (38.33%), having one perforator and one muscular branch. Pattern II (30%), having one perforator and two muscular branches (Fig. 3).

Discussion

Since the perforator base flaps were described, several myocutaneous flaps have been replaced by such flaps for resurfacing shallow defect of distal limbs[5]. The important reasons for selecting a free TDP flap are: 1) preserving muscle (the flap contains only the skin and subcutaneous adipose tissue); 2) constant thickness; 3) large flap size; and 4) a long vascular pedicle[14]. The tedious dissection of perforator of varying diameters and locations, requiring prolonged surgery, is the main disadvantage of the thoracodorsal artery perforator flap. However, this could be overcome by training and experience[11].

The pattern of the thoracodorsal artery in the latissimus dorsi muscle

The present study showed that of all the 60 dissections made, the thoracodorsal artery divided into a medial and a lateral branch, and ran on the deep surface of the muscle. This agrees very well with the preview report[13,15-18]. In the present study, all 60 dissections were (100%) made.

Some authors described the bifurcation on

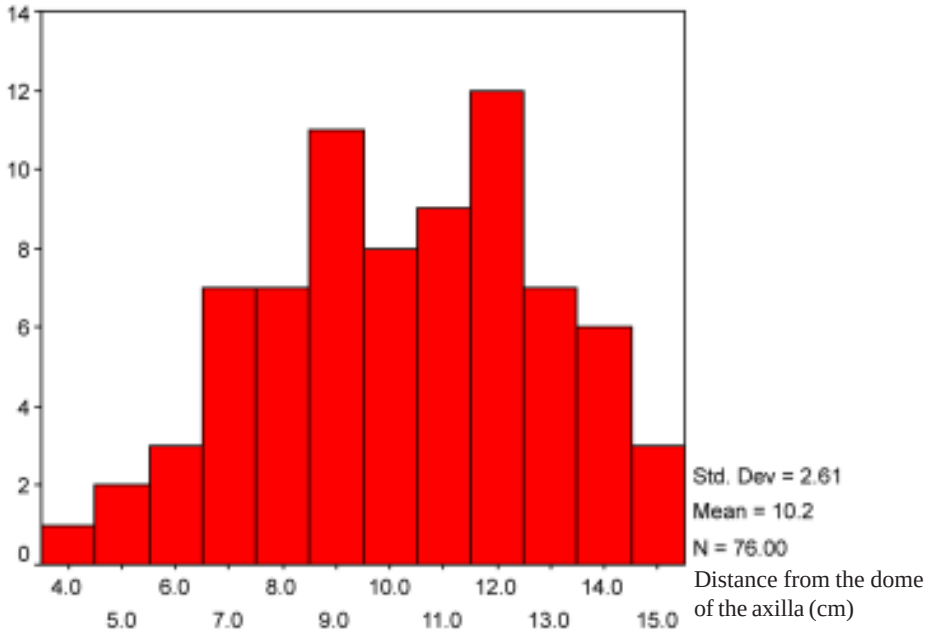

Fig. 1 The location of all the cutaneous perforators which emerged from the muscle measured from the dome of the axilla (Mean 10.2 ± 2.6 cm). Most perforators located within 7.0-14.0 cm from the dome of the axilla

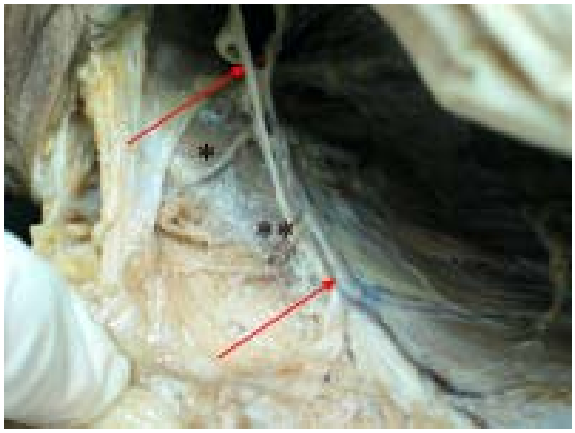

Fig. 2 A preserved cadaver specimen of a latissimus dorsi muscle viewed from the deep surface
The lateral border of the muscle had been retracted to expose the thoracodorsal artery and its cutaneous perforators; *:1st perforator; **:2nd perforator
Note the thoracodorsal nerve (top arrow) accompanied to the lateral branch of the thoracodorsal artery (bottom arrow)

the deep surface of the latissimus dorsi muscle approximately 4 cm distal to the tip of the scapula and 2.5 cm medial to the lateral free border of the muscle[13,15-18]. The present study, demonstrated that the bifurcation mostly occurred at 2 cm distal to the tip of the scapula and 1.7 cm from the lateral border of the muscle. It was also found in the present study that the bifurcation of the thoracodorsal artery was 5.0 ± 1.5 cm (range: 2.0-9.0 cm) from the dome of the axilla such structure has not been previously reported. This measurement will help in planning to obtain the TAP flap before dissection.

Bartlett[13] and Heitmann et al[18] reported that the medial branch parallel to the superior border 3.5 cm from the edge, whereas in the present results, the authors found the medial branch was 2.2 cm from the superior border of the muscle.

These anatomic findings led to the clinical refinement of the split latissimus dorsi muscle.

Number of the cutaneous perforators of the lateral branch

The TDAP flap is not a well-known flap. Recent publications have outlined the anatomy and experience with this flap, but were limited in number in contrast to other perforator flaps[19,20].

Even though Taylor et al[21] found 5 to 9 cutaneous perforators, with larger than 0.5 mm in the area of the latissimus dorsi muscle, there were no further details given regarding the specific location and origin

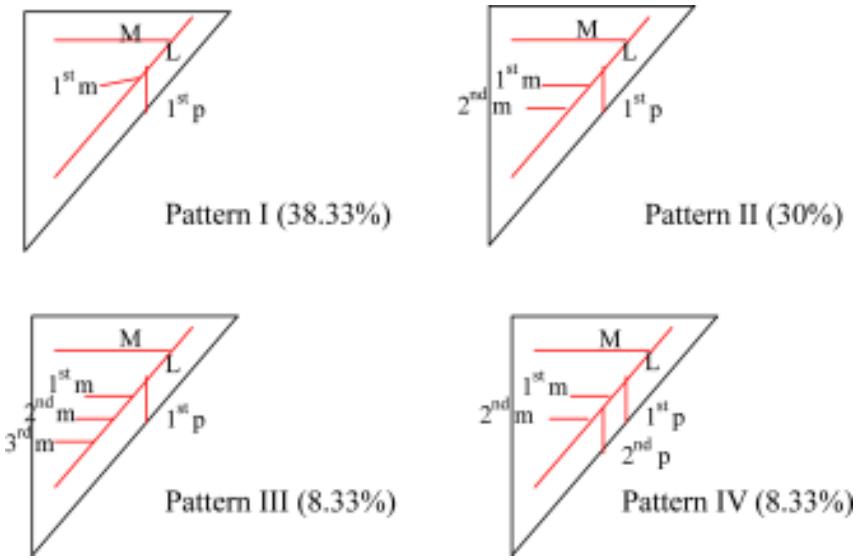

Fig. 3 Diagram showing the most common pattern of the perforators and the muscular branches of the lateral branch M, medial branch; L, lateral branch; m, muscular branch; p, perforator

Table 5. Reported series of the number of the perforators of the TDAP flap

Year	Author	Number of cadaver	Number of perforator
1987	Taylor et al[21]	-	5-9 perforators in the area
1995	Angrigiani et al[1]	40	2-3 perforators from the lateral branch
2003	Heitmann et al[18]	16	1.8 perforators (range: 1-4) from the lateral branch 1.4 perforators (range: 1-3) from the medial branch
2004	Guerra et al[19]	20	At least one perforator from the lateral branch
2005	Binu et al[2]	15	5.5 $\pm$ 1.8 perforators (range: 3-11) in the thoracodorsal artery
2004	The present study	30	1.27 $\pm$ 0.55 perforators (range: 1-3) from the lateral branch

of the perforators. Angrigiani et al[1] were the first who applied the principle of the perforator flaps to the latissimus dorsi muscle and were able to find at least one perforating vessel from the lateral branch of the thoracodorsal artery. Guerra et al[19] observed similar anatomy. Heitmann et al[18] described there was an average of 1.8 perforators of the lateral branch. Binu et al[2] reported averages of 5.5 perforators were seen from the thoracodorsal artery supplying the skin. The number of perforators of the lateral branch of the thoracodorsal artery found in the present study was 76 perforators out of larger than 0.5 mm. There was an average of 1.3 perforators (range: 1-3 perforators) (Table 5). In addition, the flap harvesting had an opportunity to find a single perforator of the lateral branch in 78.33% of specimens (Table 6). These results indicated that there were few adequate perforators from the lateral branch. This makes, the flap harvesting a very delicate procedure requiring a high level of

Table 6. The number and percent of each pattern of the perforators of the lateral branch

Pattern	Number	
1st perforator only	47	(78.3%)
1st, 2nd perforator	10	(16.7%)
1st, 2nd & 3rd perforator	3	(5.0%)
Total	60	(100%)

microsurgical skill, and must be carried out meticulously.

The number for each perforator of the lateral branch reported by several authors is shown in Table 8. In the present study, the first perforator was in all dissections (100%), while the second and third perforators were found in 21.67 and 5%, respectively. In accordance with other studies, Table 7 showed that the first perforator was always the largest and most consistent. The second and the third perforators were smaller and less consistent[19].

Location of the cutaneous perforators of the lateral branch of the thoracodorsal artery

The location and distribution of these perforators have not been adequately described previously. Using the Duplex ultrasound scan to locate the perforators is not accurate enough because it is difficult to distinguish between the signal of a perforator and the main pedicle due to the relatively thin layer of the subcutaneous tissue[20]. Therefore, knowledge of the specific location of the perforator is very important in the perforator flap harvesting.

Table 7. Anatomy studies of the thoracodorsal artery perforating vessels

Year	Author	1st perforator	2nd perforator	3rd perforator
1995	Angrigiani et al[1]	40/40	40/40	32/40
2003	Heitmann et al[18]	20/20	13/20	2/20
2004	Guerra et al[20]	17/20	12/20	10/20
2004	The present study	60/60	13/60	3/60

Table 8. Published series of the TDAP flap about the location of the perforator of the lateral branch

Year	Author	1st perforator	2nd perforator	3rd perforator
1995	Angrigiani et al[1] (50 fresh cadavers)	8 cm from posterior axillary fold 2-3 cm from lateral border of muscle	2-4 cm from the origin of the 1st perforator	2-4 cm from the origin of the 2nd perforator
1996	Spinelli et al[10] (6 fresh cadavers)	The perforating vessels located directly over the lateral branch of the thoracodorsal artery		
2001	Kim et al[5](12 case)	Perforator near the lateral border of muscle		
2003	Heitmann et al[18] (16 fresh cadavers)	All perforators originated within a distance of 8 cm from the bifurcation		
2004	Guerra et al[20] (20 cadavers)	2-4 cm from the bifurcation	2-6 cm from the origin of the 1st perforator	-
		All perforator originated within a distance of 8 cm from the bifurcation		
2005	Binu et al[2] (15 fresh cadavers)	Inferior angle of the scapula 3 cm from lateral border of muscle	2.5-4 cm from the origin of the 1st perforator	-
2004	The present study (30 preserved cadavers)	9.8 $\pm$ 2.6 cm from dome of axilla 1.7 $\pm$ 0.6 cm from lateral border of muscle	3.4 $\pm$ 2.1 cm from the origin of the 1st perforator	3.0 $\pm$ 1.6 cm from the origin of the 2nd perforator

The first effort to locate the perforators by using the posterior axillary fold and the anterior border of the latissimus dorsi muscle as landmarks was performed. Angrigiani et al[1] first used these landmarks in their original description of the thoracodorsal artery perforator flap. In addition, as pointed out by Binu et al[2] that the identification of the perforator by using the anterior border of the latissimus dorsi muscle and the lowest point of the scapula is useful. Spinelli et al[10] described this row of perforating vessels located directly over the lateral branch of the thoracodorsal artery. Kim et al[5] also reported these similar anatomical findings. Whereas in the present study, the first perforators exited the muscle into the subcutaneous tissue approximately 9.8 cm below the dome of the axilla and 1.7 cm posterior to the lateral border of the muscle. The second perforator arose 3.4 cm distal to the origin of the first perforator. The third perforator arose 3 cm distal to the origin of the second perforator (Table 3, 8).

Heitmann and Guerra[18,19] reported that all the cutaneous perforators were within 8 cm of the bifurcation. Whereas the present study, showed that all the cutaneous perforators were within 10 cm of the bifurcation.

In addition, the present study showed the location of all of the perforators (76 perforators), penetrating the muscle at an average distance of 10.2 $\pm$ 2.6 cm from the dome of the axilla (range: 4.1-14.8 cm). In the majority of dissections (88.2%, 67 of 76 perforators), the perforators were located in a range between 7 to 14 cm distal to the dome of the axilla. In 53 of 60 flaps (88.3%), these were at least one perforator in this range. In the remaining 7 of 60 flaps (11.7%), no perforator was found in this range. In addition, focused on the location of the perforators ranging from 9 to 12 cm distal to the dome of the axilla. In the present study, at least one perforator in 35 of 60 flaps (58.3%) was noted. In the remaining 25 of 60 flaps (41.7%), perforators were not found in this range. For designing of the flap, the authors suggested that the perforator flap harvesting area should range from 7 to 14 cm distal to the dome of the axilla (Fig. 1).

It should be noted that as all the perforators were thin, fragile, and obliquely course, then the dissection of the perforator might be difficult. It is recommended that several strips of muscle fiber sore left attached to the perforator to assure safe dissection and prevent kinking or undue tension of the perforator during flap inset[4].

In clinical experience, to harvest the flap, the patient has to be positioned in the lateral decubitus position with abducted to 90 degrees at the shoulder, whereas, in the present study, the cadavers were placed in the supine position with the shoulder abducted to 90 degrees. The position of the cadaver might have influenced the location of the perforators. However, the difference might not be significant because it was previously fixed by formal in during embalming.

Conclusion

The present study elucidates the anatomy of the thoracodorsal artery and the cutaneous perforators were of the lateral branch within the latissimus dorsi muscle. Most perforators located approximately 7 to 14 cm from the dome of the axilla. This should be an important guideline to design and support the clinical use of the TDAP flap.

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กายวิภาคของหลอดเลือดแดงทอราโคดอร์ซอลในเพอฟอเรเทอร์แฟล็บ เพื่อประยุกต์ใช้ในการซ่อมแซมบริเวณพื้นผิว ของร่างกายที่สูญเสียไป

ธันวา ตันสถิตย์, ประยุทธ์ โชครุ่งวรานนท์, สำอาง วณิชชาพลอย, ภาสินี สงวนสิทธิ์

วัตถุประสงค์: *เพื่อศึกษาถึงตำแหน่งและจำนวนของหลอดเลือดเพอฟอเรเทอร์ ที่มีเส้นผ่านศูนย์กลางมากกว่า 0.5 มิลลิเมตรของแขนงแลทเทอรัล ของหลอดเลือดแดงทอราโคดอร์ซอล เพื่อประยุกต์ใช้ในการซ่อมแซมบริเวณพื้นผิวของร่างกายที่สูญเสียไป*

วัสดุและวิธีการ: *ทำการศึกษาในศพดองที่รักษาสภาพด้วยฟอร์มาลีนจำนวน 30 ท่าน (60 แฟล็บ) โดยนับจำนวนและวัดตำแหน่งของเพอฟอเรเทอร์ จากจุดยอดของรักแร้ถึงตำแหน่งที่ทะลุขึ้นกล้ามเนื้อของเพอฟอเรเทอร์ ที่มีเส้นผ่านศูนย์กลางมากกว่า 0.5 มิลลิเมตร*

ผลการศึกษา: *ใน 60 แฟล็บ พบหลอดเลือดเพอฟอเรเทอร์ทั้งหมด 76 หลอดเลือด เฉลี่ย 1 หลอดเลือด ต่อ แฟล็บ โดย หลอดเลือดเฟิร์ซท์ เพอฟอเรเทอร์มีขนาดใหญ่ที่สุดและพบในศพดองทั้งหมด ส่วนตำแหน่งที่ทะลุขึ้นกล้ามเนื้อพบว่าอยู่ต่ำกว่าจุดยอดของรักแร้ เฉลี่ย 9.8 ซม. ห่างจากขอบข้างของกล้ามเนื้อเฉลี่ย 1.7 ซม. หลอดเลือดเซคเคินด์ เพอฟอเรเทอร์ พบ 13 ใน 60 แฟล็บ อยู่ห่างจากหลอดเลือดเฟิร์ซท์ เพอฟอเรเทอร์เฉลี่ย 3.4 ซม. หลอดเลือดเธิร์ด เพอฟอเรเทอร์ พบ 3 ใน 60 แฟล็บ อยู่ห่างจากหลอดเลือดเซคเคินด์ เพอฟอเรเทอร์เฉลี่ย 3.0 ซม. นอกจากนี้ เพอฟอเรเทอร์ที่ออกมาจากแขนงแลทเทอรัล ส่วนใหญ่ทะลุขึ้นกล้ามเนื้อในบริเวณ 7.0-14.0 ซม. จากจุดยอดของรักแร้และอยู่ใกล้ขอบข้างของกล้ามเนื้อ*

สรุป: *ความรู้ที่ได้จากการศึกษาในครั้งนี้ สามารถนำไปใช้ในการออกแบบแฟล็บ, ช่วยลดเวลาในการผ่าตัด และนำไปประยุกต์ใช้ในทางคลินิกต่อไป*