Anatomical study of the anterolateral perforators of the thigh and its clinical applications

Habiba A.T.M. El-Shennawy[1], Elsayed S. Atta-Allah[2], Ehab M. Elzawawy[3], Sally M.M.H. Omar[4]

[1]Assistant lecturer, Department of Anatomy and Embryology, Faculty of Medicine, Alexandria University, Alexandria, Egypt
[2] Professor, Department of Anatomy and Embryology, Faculty of Medicine, Alexandria University, Alexandria, Egypt
[3] Professor, Department of Anatomy and Embryology, Faculty of Medicine, University of Alexandria and National University of Science and Technology,Oman. Alexandria, Egypt
[4] Lecturer, Department of Anatomy and Embryology, Faculty of Medicine, Alexandria University, Alexandria, Egypt

SUMMARY

Anterior thigh skin continued over the years to provide advantageous donor sites for reconstructing defects all over the body. Reconstructive surgery has undergone unceasing alterations and modifications with the sole purpose of securing the best aesthetic and functional outputs. Of these alterations, a landmark shift was brought about by the concept of axiality, which stated that flaps should be categorized according to their vasculature. From there on, more attention was directed to understanding the precise arterial supply of the skin. This article aims to study the cutaneous perforators of the anterolateral thigh and explains their significance in flap design.

The material of the present study included thirty fresh cadaveric lower limbs. The external iliac artery (EIA) was injected with colored latex. Superficial, then deep, dissections were undertaken under a magnifying lens to locate the perforators and identify their type according to Cormack's and Lamberty's tripartite system: direct, fasciocutaneous and musculocutaneous perforators. The length and diameter of the perforators were measured.

Anterolateral thigh skin was divided into 3 squares. Square 1 is the upper square and comprises the skin over tensor fascia lata (TFL). It is primarily based on the lateral circumflex femoral artery (LCFA), mainly its transverse branch (TB). It divided into three muscular arteries to TFL upon entry of the muscle; upper, middle and lower, and they provided a musculocutaneous perforator in 100%, 60% and 40%, respectively. Squares 2 (middle) and square 3 (lower) are those infamously called the anterolateral thigh flap (ALTF). They are the rest of the anterolateral thigh skin below the TFL and down to the knee. They are mainly based on the descending branch (DB) of the LCFA. It gave two fasciocutaneous perforators at its beginning and termination in all cases; the highest one was for square 2 and the lowest for square 3. The anterolateral thigh skin is richly supplied by a mixture of the three types of perforators. The segmental nature of the perforators arising from the (DB) of the LCFA, together with the superbly long

Corresponding author:
Dr. Sally Mahmoud Mohamed Hussein Omar, Department of Anatomy and Embryology, Faculty of Medicine, Alexandria University, Alexandria, Egypt, E Mail: omarsasa@ymail.com

Submitted: July 5, 2021. **Accepted:** October 25, 2021

course of the artery itself, grants the famous ALTF its versatility.

Key words: Anterolateral thigh – Perforators – Flap

INTRODUCTION

Throughout the years, the lower limb in general and the thigh specifically remained the largest and preferred donor site in the human body for flap harvest (Landuyt, 2006). This is due to the rich vascularity, ease of access, ability to obtain large surface areas for tissue coverage, versatility in the flap design and the hidden postoperative donor site scar (Chan et al., 2014; Morris and Taylor, 2013; Geddes et al., 2013).

The development of regional and free flaps has been, and continues to be, the most exciting and essential of the advances in plastic surgery. The ability to guarantee survival of the transferred tissue continued to pose a challenge, and it is not until the early nineteenth century that another milestone was reached when researchers came to understand that the anticipated survival of a flap depended primarily on its vascularization (Morris et al., 2010; Cormack and Lamberty, 1994).

However, the dilemma of good flap survival with minimal thickness persisted to provoke anatomists and surgeons to search for methods to secure the vitality of thin flaps. This was made possible with the emergence of perforator flaps between the 1980s and 1990s (Park et al., 2018).

It is for these reasons that sound knowledge of the vascular anatomy of the human skin provides the framework for successful flap elevation. Therefore, it is essential for the reconstructive surgeon to have a proper understanding of the vascular anatomy of the integument.

In perforator-based flaps, the impetus of vascular knowledge has shifted from the source artery to the perforator itself. By definition, a perforator is any vessel that pierces the upper layer of the deep fascia to supply the overlying subcutaneous tissue and the skin (Chan et al., 2014; Cormack and Lamberty, 1994; Mathes and Nahai, 1997).

Cormack and Lamberty's tripartite system proved to be the simplest yet most practical for classification of perforators (Timmons, 1985). They categorized them according to the path taken from the parent vessels into three main types: direct cutaneous perforators, fasciocutaneous perforators and musculocutaneous perforators. In essence, a single perforator can be a mixture of two types (Cormack and Lamberty, 1994).

MATERIAL AND METHODS

The study was conducted on 30 fresh cadaveric lower limbs obtained from the department of Human Anatomy and Embryology, Alexandria Faculty of Medicine. Injection material comprised ammonium solution 25% concentration, tap water, liquid rubber as a solidifying matter and a red liquid dye. The material was intravascularly injected through catheters of different sizes. For magnification: an overhead times three magnifier was used with a built-in LED light source. Measuring instruments included a digital Vernier Caliper and a flexible measuring tape.

A high inguinal incision was made above and parallel to the intermediate third of the line extending from the anterior superior iliac spine (ASIS) to the pubic tubercle (PT). Careful dissection was then undertaken through the layers of the abdominal wall until visualization of the EIA.

Once identified, catheterization of the artery was done followed by flushing with ammonium solution to dissolve any possible thrombi. Afterwards, a mixture of Latex, water and a red dye was injected with an average of 30-50 ml of the mixture and the cadaver was allowed to cool down to 4ºC for one week to solidify the latex before dissection. The previously cut inguinal incision was then extended medially and then downwards from the PT along the whole length of the medial thigh till the medial tibial condyle (MTC). The direction of skin elevation was from medial to lateral till the posterior (lateral) edge of the Vastus Lateralis (VL).

The anterolateral thigh territory was divided into three squares according to four cardinal lines. The first line extending between ASIS to the lateral patellar margin, and the second line corresponds to the lateral margin of the thigh which is presented by a line tangential to the greater trochanter extending to the lateral tibial condyle (LTC). This column was subdivided to three regions; upper

(square 1), middle (square 2) and lower (square 3), according to two horizontal planes. One at the level of apex of the femoral triangle and the other midway between the first horizontal line and the knee joint line. This produced a total of three squares, and each will be regarded as a separate entity with its own perforators. The type and origin were then determined, and the following measures were taken using the digital caliper and flexible tape: diameter, length, underrunning distance and site. The three fundamental types were: Type 1, Direct cutaneous; Type 2, Fasciocutaneous, and Type 3, Musculotcutaneous. This also warrants that there may be a combined type.

RESULTS

Square 1:

This area comprised the skin over TFL. It is relatively rich in vascularity, and was mainly supplied by the superficial circumflex iliac perforator. A total of 7 perforators were observed as follows:

- The superficial circumflex iliac perforator in 30 limbs (100%).
- One lateral fasciocutaneous perforator from the ascending branch (AB) of LCFA in 6 limbs (20%).
- Three musculocutaneous perforators from the TB of LCFA: the first in 30 limbs (100%), the second in 20 limbs (66.6%), and the last in 12 limbs (40%).
- Two fasciocutaneous perforators from the DB of the LCFA: one from the oblique branch (OB) in 8 limbs (26.6%) and another from the main stem of DB in all limbs.

The AB of the LCFA arose at an average distance of 12.25±0.7 cm inferomedial to the ASIS. It came off undercover of Sartorius (S) then ascended upwards towards the ASIS superficial to the iliopsoas (IP) and upper part of rectus femoris (RF). It finally appeared after passing between S and TFL at a mean distance of 4.2±0.5 cm below the ASIS. Its mean caliber was 2±0.1 mm and total running distance was 11±0.8 cm (Fig. 1).

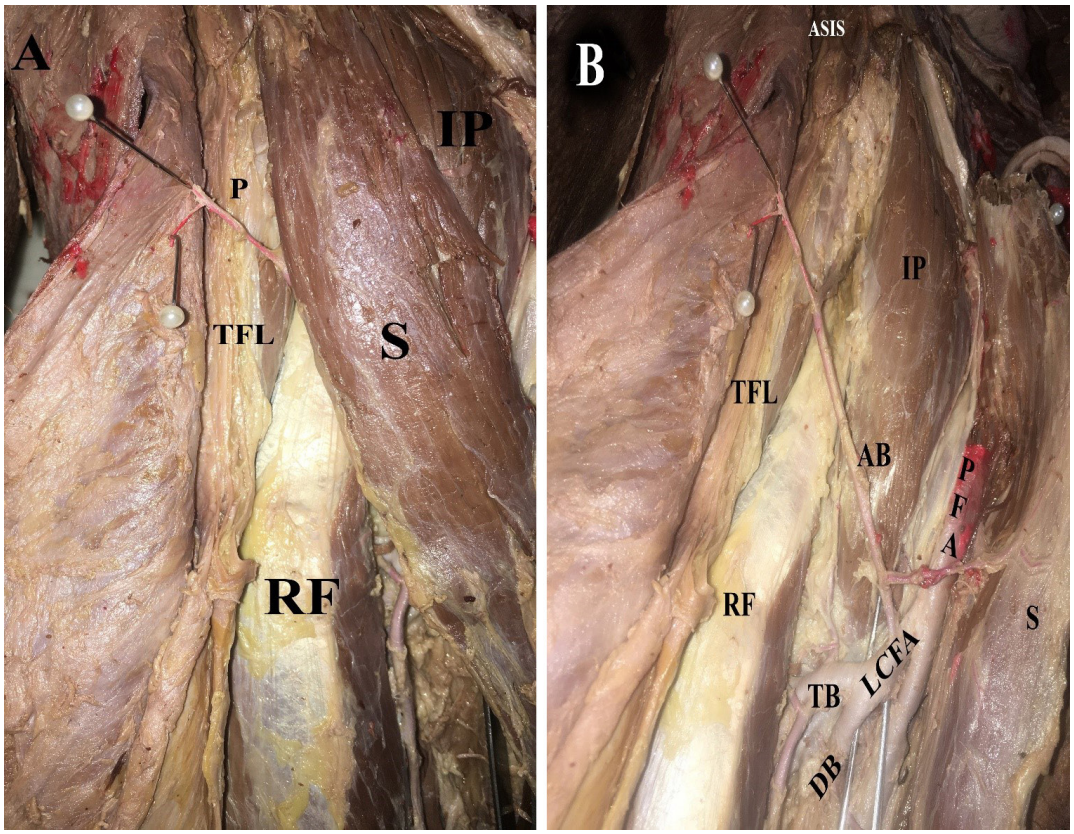

Fig. 1.- A: a photograph of the uppermost lateral skin of right thigh showing a fasciocutaneous perforator (P) emerging between sartorius (S) and tensor fasciae latae (TFL)., **B:** after medial reflection of S, this perforator is the termination of the ascending branch (AB) of the lateral circumflex femoral artery (LCFA). It is noticed that the AB came off the profunda femoris artery (PFA) under S and continued to run over the iliopsoas (IP) and upper rectus femoris (RF) to finally emerge between S and TFL supplying an area of skin (Sk) just below the anterior superior iliac spine (ASIS). TB: transverse branch, DB: Descending branch.

The TB of LCFA arose deep to the S and the RF to enter the substance of TFL. Upon its entrance, it divided into three branches: upper, middle and lower. The three branches gave corresponding musculocutaneous perforators, yet with different percentages (Fig. 2). The musculotcutaneous perforator of the upper division was constant in all limbs, the second branch gave its perforator in 20 limbs (66.6 %), and lastly the third was the least (40%). The site of the three musculocutaneous perforators were 8.8±0.2 cm, 10.16±0.2 cm, and 11±0.5 cm below the ASIS respectively. The largest and the longest was the first with a mean caliber of 0.7±0.2 mm and length of 3.5±0.7 cm, followed by the second, whose diameter was 0.47±0.09 mm and length was 0.48±0.1 cm and lastly the third with a caliber of 0.46±0.1 mm and length of 0.39±0.1 cm.

The DB of LCFA in this square gave two fasciocutaneous perforators one from the main stem and another from its OB. The DB of LCFA took origin from the LCFA deep to the S and RF, then continued inferolaterally to reach the anterior border of the VL, where it gave in all limbs a fasciocutaneous perforator, which emerged between the RF and VL at a mean distance of 18.1±1 cm inferomedial to the ASIS. This perforator also continued downwards for a mean distance of 3±1 cm to supply square 2. Its mean diameter was 1.2±0.1 mm, and mean total length was 8.5±0.2 cm. Additionally, in 8 limbs (26.6 %), the DB of LCFA gave OB before it reached the anterior border of VL, in which case this OB also gave a fasciocutaneous perforator that emerged between RF and VL. It appeared at a mean distance of 15±0.5 cm below and medial to the ASIS. Its mean diameter was 1.2±0.2 mm, and its length was 4.8±0.4 cm. The DB of LCFA then continued downwards sandwiched between VL and vastus intermedius (VI). The two perforators are shown in Fig. 3.

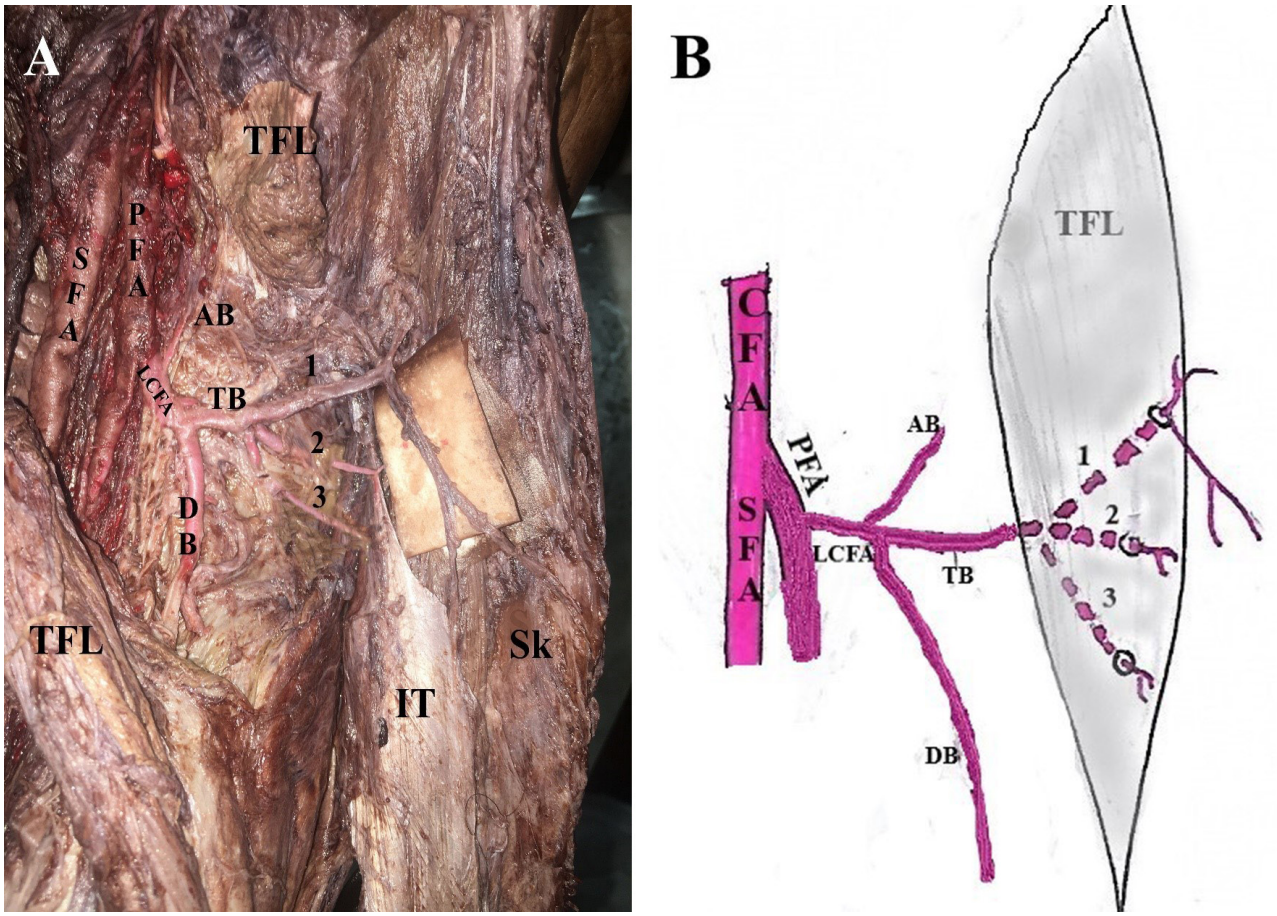

Fig. 2.- A: a photograph of the upper lateral area of left thigh showing the tensor fasciae latae (TFL) divided to reveal inside it the pattern of division of the transverse branch (TB) of the lateral circumflex femoral artery (LCFA). The TB ramified to three branches; upper 1, middle 2, and lower 3, each giving respective musculocutaneous perforators. It is noticed that the sizes of the perforators decreased from the first to the third branch., **B:** is a diagrammatic illustration. CFA: Common femoral artery, SFA: superficial femoral artery, PFA: profunda femoris artery, IT: iliotibial tract, Sk: Skin, AB: ascending branch, DB: descending branch.

The mean length (cm), mean diameter (mm) and distance from ASIS (cm) of all identified perforators in square 1 are shown in Table 1.

Square 2:

This is the area over the middle bulkiest portion of the VL. This area displayed the highest percentage of type 2 and 3 perforators. All perforators came from the DB of LCFA, except one fasciocutaneous perforator from the profunda femoris artery (PFA) as follows:

- One fasciocutaneous perforator from the DB of LCFA, which was shared with the above square in 30 limbs (100%).
- Four musculocutaneous VL perforators from the DB of LCFA, three of which were present in all limbs 100% and one in 25 limbs (83.3 %).

The DB of LCFA took origin 13.3±0.4 cm inferomedial to the ASIS. It ran for about 1-2 cm, then gave an OB during its course towards the VL in 8 limbs. Upon its arrival at the anterior border of VL, it constantly provided a fasciocutaneous perforator (Fig. 3). Afterwards, it continued downwards between the VL and VI, where it gave off four musculocutaneous perforators. Three of these were present in all limbs and one was found in 25 limbs. From above downwards, they were located at distances 22.15±0.4, 25.3±0.7,

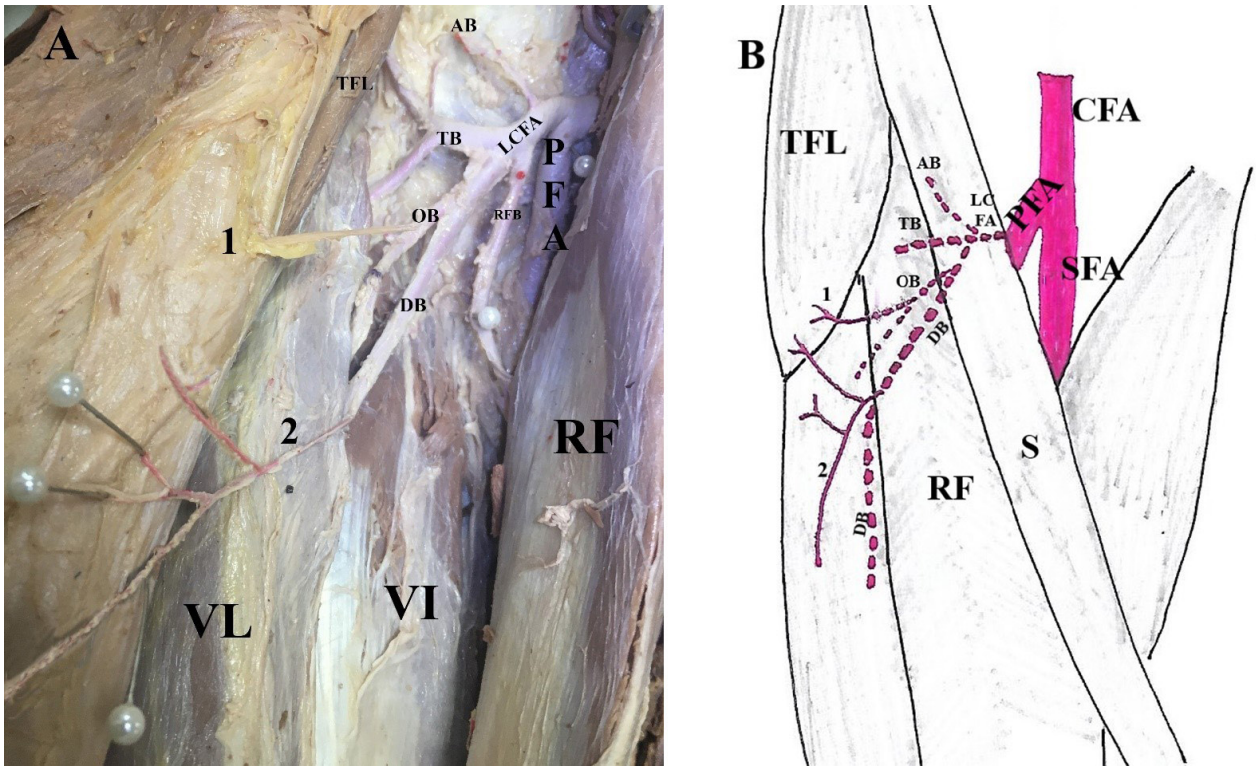

Fig. 3.- A: a photograph of the upper lateral part of right thigh showing two fasciocutaneous perforators (1 and 2) emerging between the rectus femoris (RF) which is reflected medially and vastus lateralis (VL). The first originated from the oblique branch (OB) of lateral circumflex femoral artery (LCFA) and the second from the descending branch (DB) at the anterior border of VL. The DB then disappeared between VL and vastus intermedius (VI). These two perforators supply the lower part of the skin (Sk) over the tensor fasciae latae (TFL) and the second continued to some distance downwards to reach the square below, **B:** is a diagrammatic illustration with the RF in place. CFA: common femoral artery, SFA: superficial femoral artery, PFA: profunda femoris artery, AB: Ascending branch, TB: Transverse branch, RFB: Rectus femoris branch.

Table 1. The mean length (cm), mean diameter (mm) and distance from ASIS (cm) of all identified perforators in square 1

Origin of perforator	AB of the LCFA	TB of LCFA			DB of LCFA	
		First	second	third	From main stem	From OB
Mean length (cm)	11±0.8	3.5±0.7	0.48±0.1	0.39±0.1	8.5±0.2	4.8±0.4
Mean diameter (mm)	2±0.1	0.7±0.2	0.47±0.09	0.46±0.1	1.2±0.1	1.2±0.2
Distance from ASIS	4.2±0.5	8.8±0.2	10.16±0.2	11±0.5	18.1±1	15±0.5

26.9±2.3, and 27.5±0.6 cm distal to the ASIS. The size of these perforators gradually decreased as we go downwards; their mean calibers were 0.69±0.2, 0.54±0.1, 0.54±0.06, 0.5±0.1 mm and mean lengths were 2.4±0.2, 1.69±0.1, 1.38±0.2, 0.6±0.1 cm respectively (Fig. 4). The mean length (cm), mean diameter (mm) and distance from ASIS (cm) of all identified perforators in square 2 are shown in Table 2.

Square 3:

This is the area over the lowest part of the VL. It received the termination of the DB of LCFA in addition to superolateral genicular artery (SLGA) from the popliteal artery (PA). A total of 4 perforators were found as follows:

- Two musculocutaneous from the DB of LCFA; one in 30 limbs (100%) and the other in 20 limbs (66.6%).

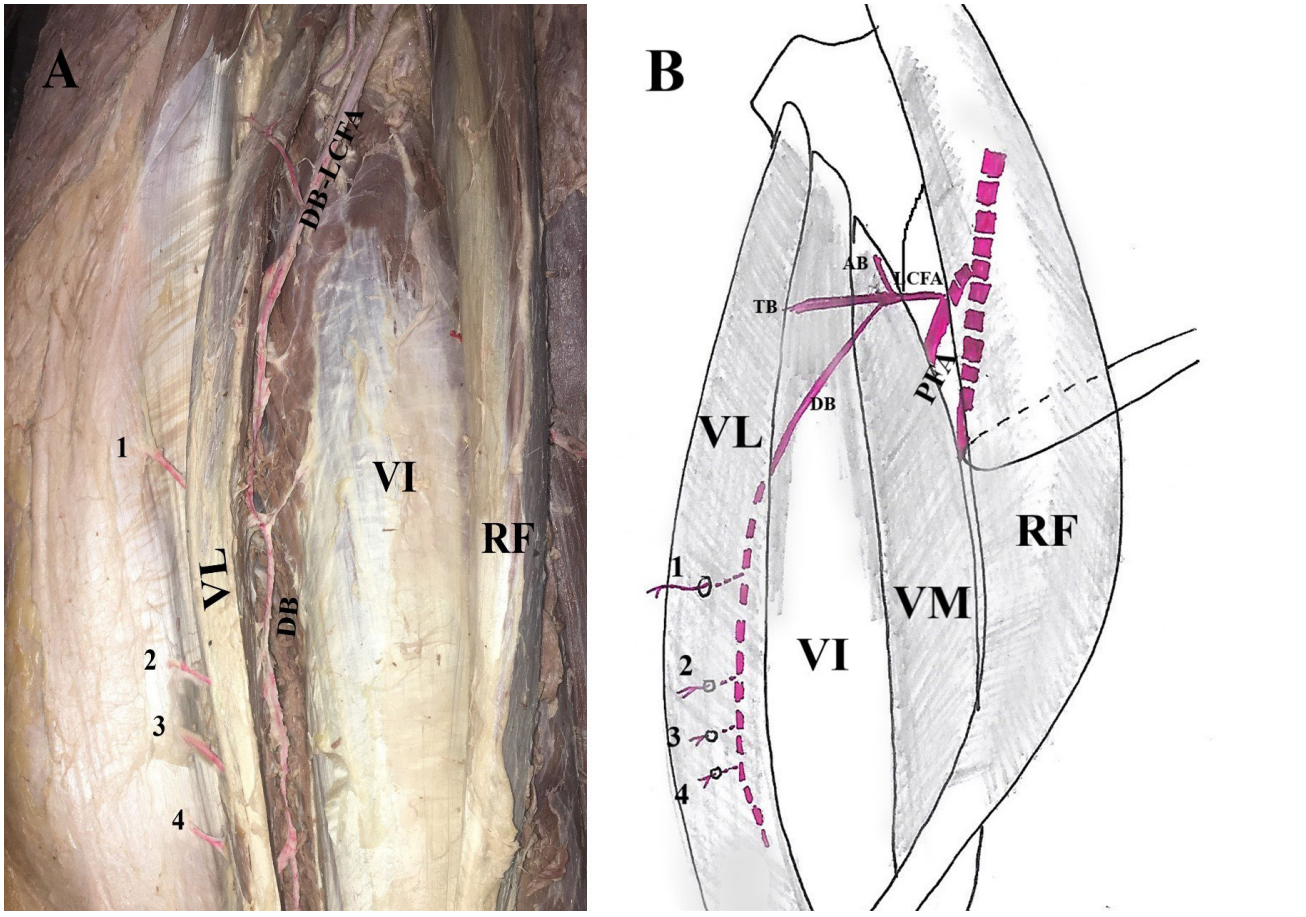

Fig. 4.- A: a photograph of the front of right thigh showing the Descending branch (DB) of lateral circumflex femoral artery (LCFA) passing between the vastus lateralis (VL) and Vastus intermedius (VI) giving off several musculocutaneous perforators (1, 2, 3, and 4) through the vastus lateralis. The rectus femoris (RF) is reflected medially., **B:** is a diagrammatic illustration. PFA: profunda femoris artery, AB: ascending branch, TB: transverse branch, VM: Vastus medialis. Sk: Skin.

Table 2. The mean length (cm), mean diameter (mm) and distance from ASIS (cm) of all identified perforators in square 2

Origin of perforator	Four musculocutaneous perforators from the DB of LCFA			
	First	Second	Third	Fourth
Mean length (cm)	2.4±0.2	1.69±0.1	1.38±0.2	0.6±0.1
Mean diameter (mm)	0.69±0.2	0.54±0.1	0.54±0.06	0.5±0.1
Distance from ASIS	22.15±0.4	25.3±0.7	26.9±2.3	27.5±0.6

- The lowest fasciocutaneous perforator of the DB of LCFA in all limbs.
- SLGA from the PA in all limbs.

The terminal part of the DB of LCFA in this region gives off two musculocutaneous perforators. They were located at a mean distance of 11.5±2.7 and 11±0.8 cm proximal to LTC. Their mean diameters were 0.4±0.09 and 0.5±0.5 mm and their lengths were 1.13±0.1 and 1.12±0.09 cm. The DB of LCFA gave a fasciocutaneous perforator that emerged between the tendinous part of RF and VL at a point 8.7±0.6 cm above LTC. It measured 0.5±0.1 mm in diameter and 1.4±0.1 cm in length (Fig. 5). All perforators that came from the DB of the LCFA to the anterolateral thigh skin were shown in figure 6. The perforators were 2-4 cm apart.

In all cases, the SLGA arose from the PA at a mean distance of 7.7±0.5 cm above LTC, then ran laterally in the lateral intercompartmental septum to emerge between the short head of biceps posteriorly and the VL anteriorly. It then curved anteriorly dividing into two branches to supply an area of skin overlying the VL and even continued to some distance medially over the tendinous RF. Its mean diameter was 2.1±0.06 mm and total length was 9.3±0.54 cm. (Fig. 7).

The mean length (cm), mean diameter (mm) and distance from LTC (cm) of all identified perforators in square 3 are shown in Table 3.

DISCUSSION

Many factors co-exist to define the reliability of a potential flap, such as its color, hairiness, elasticity, thickness and cutaneous sensitivity (Cormack and Lamberty, 1994). However, this study stresses the importance of sound knowledge of vascular anatomy as a cornerstone to carry out a successful tissue transfer. Anatomical studies help explore well-vascularized skin areas and prove them suitable choices as potential flaps.

Flaps have evolved from muscle-based flaps to specific perforator-based flaps. This preserves the underlying muscle, reduces donor site morbidity, and adds greater versatility to the design of a flap. Better understanding of the vascular anatomy of the skin can greatly advance and improve flap design (Mohan and Saint-Cyr, 2015).

The anterolateral thigh flap based on the DB of LCFA was first reported as a new free flap by Song et al. (1984). It was developed for widespread clinical applications by Koshima et al. (1993) and Kimata et al. (1998). It continued over the years

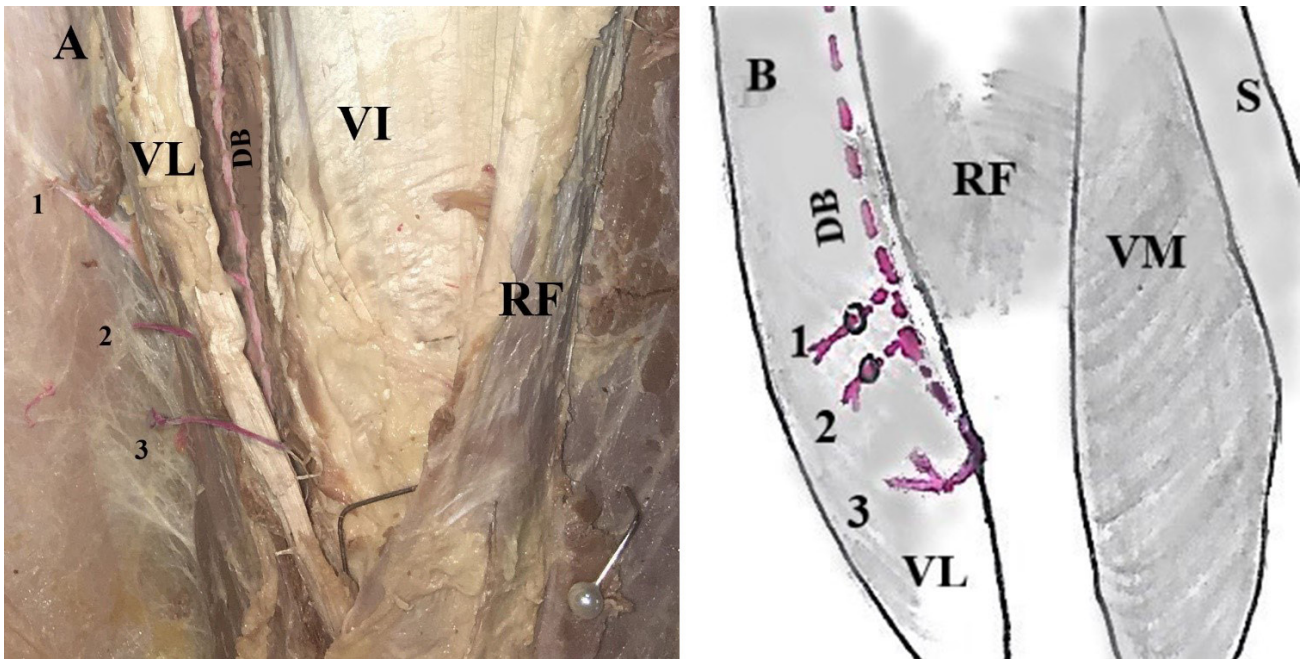

Fig. 5. A: a photograph of right thigh showing the right terminal part of the descending branch (DB) of the lateral circumflex femoral artery of LCFA giving three perforators laterally (1, 2 and 3). Perforators 1 and 2 are musculocutaneous and 3 is a fasciocutaneous perforator that passed between the lowest part of rectus femoris (RF) and vastus lateralis (VL)., **B:** is a diagrammatic illustration. VI: vastus intermedius, VM: vastus medialis, S: sartorius. Sk: Skin.

to present many advantages like its moderate thickness, and large area with availability of different tissues, which allow for aesthetic and functional refinement. It can be as thin as the radial forearm flap and hence, much preferred as a donor site since the forearm flap leaves a visible scar (Terrell et al., 2018; Succio, 2014). Yet, in many times it showed difficult dissection as the perforating arteries of the DB of the LCFA that exhibited widely different anatomic variations especially the distally-based flap (Terrell et al., 2018).

The LCFA was reported in literature to have variable origin. Cormack and Lamberty (1994) stated that 75% arose from the PFA, while the remainder arose directly from the femoral artery. They also stated that the DB may arise directly from the PFA. Maricivech et al. (2017) reported that the LCFA originated from the PFA (83%), the common femoral artery (13.5%), and the superficial femoral artery (3.5%).

The results of the present study showed that the main LCFA arose from the PFA in all cases. It divided into its three classical branches; AB, TB and DB. The DB of the LCFA is classically described to originate deep to S and RF, then descended downwards on the medial border of the VL and intervened between it and RF, then between the VL and VI as it continued downwards to terminate inside the VL near the knee (Landuyt, 2006; Kimata et al. 1998; Yamada et al., 2014; Standring, 2008).

This study showed that the DB of the LCFA originated deep to the S and RF, then continued infero-laterally to reach the anterior border of the VL. At this point it provided OB in 26.6% of cases. It then continued downwards, sandwiched between

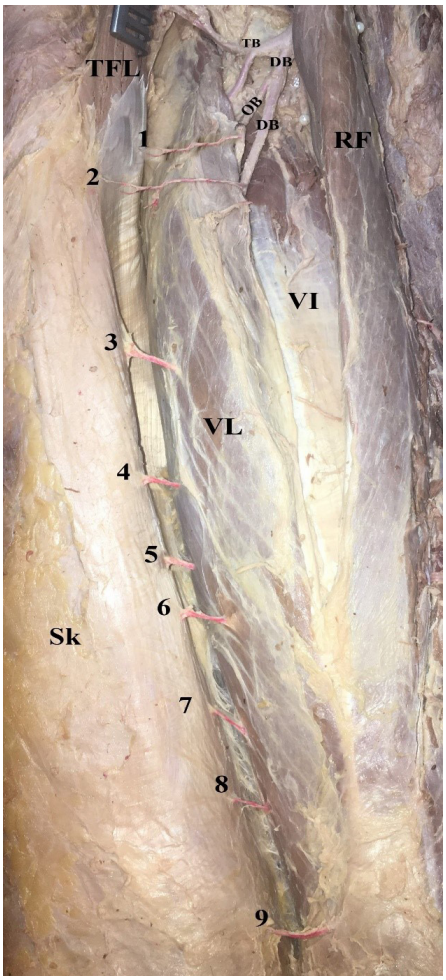

Fig. 6.- A photograph of the anterolateral aspect of right thigh showing the fasciocutaneous and musculocutaneous perforators collectively that originated from the descending branch DB of the lateral circumflex femoral artery. There are nine perforators (1 to 9). Perforators 1, 2, and 9 are fasciocutaneous. Perforator 1 originated from the oblique branch (OB) followed by perforator 2 from the main stem of the DB and perforator 9 is the lowest fasciocutaneous perforator emerging between the lowest tendinous parts of rectus femoris (RF) and vastus lateralis (VL). Perforators 3, 4, 5, 6, 7, and 8 are musculocutaneous perforators through VL. TB: Transverse branch, TFL: Tensor fasciae latae, VI: Vastus intermedius, Sk: Skin.

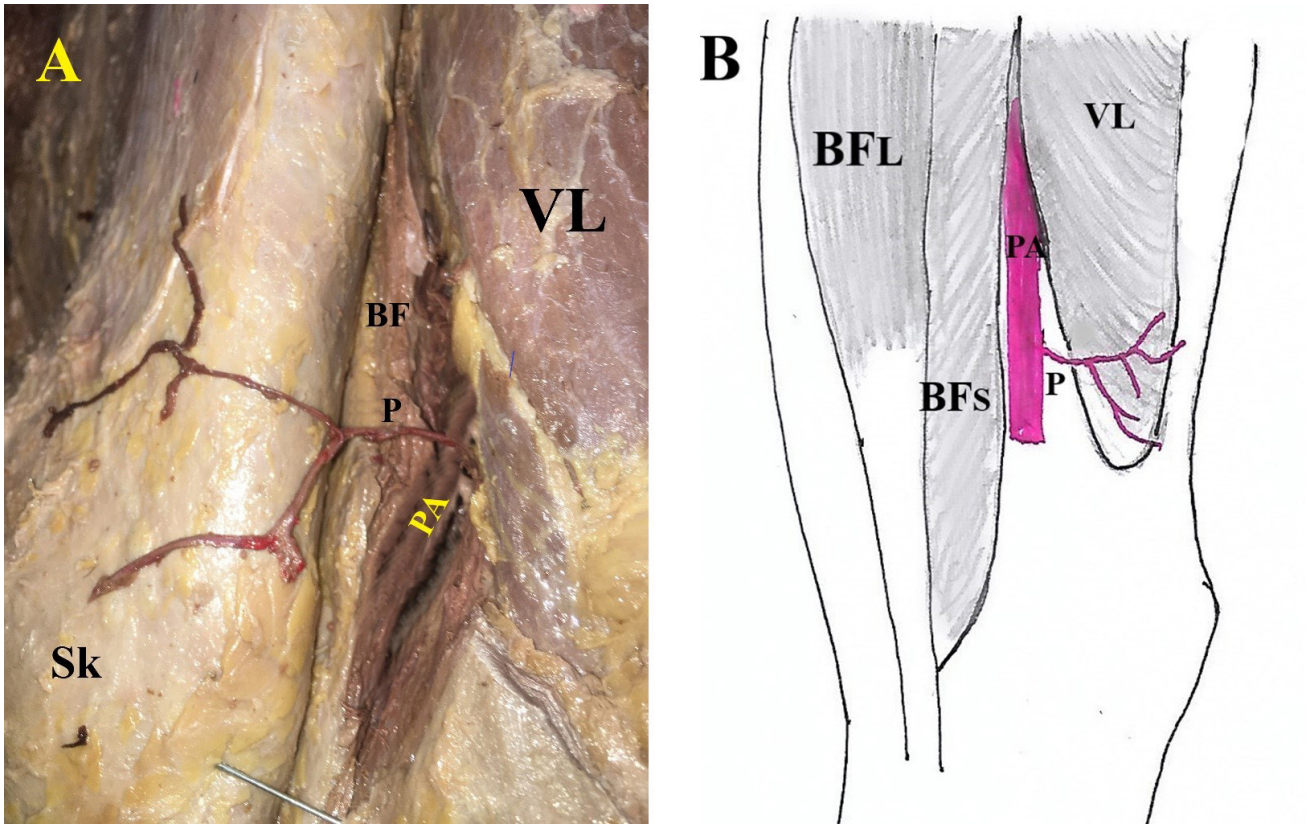

Fig. 7.- A: a photograph of the lower lateral area of right thigh showing the popliteal artery (PA) giving off a lateral fasciocutaneous perforator (P) between the biceps femoris (BF) and the vastus Lateralis (VL). It curved around the lower lateral border of VL dividing into two branches to supply the overlying skin (Sk)., **B:** is a diagrammatic illustration, BFL: long head of Biceps femoris, BFs: short head, IT: Iliotibial tract.

Table 3. The mean length (cm), mean diameter (mm) and distance from LTC (cm) of all identified perforators in square 3

Origin of perforator	Musculocutaneous from DB of LCFA		Lowest fasciocutaneous perforator of the DB of LCFA	SLGA from the PA
	First	Second		
Mean length (cm)	1.13±0.1	1.12±0.09	1.4±0.1	9.3±0.54
Mean diameter (mm)	0.4±0.09	0.5±0.5	0.5±0.1	2.1±0.06
Distance from LTC	11.5±2.7	11±0.8	8.7±0.6	7.7±0.5

VL and VI giving off several fasciocutaneous and musculocutaneous perforators; it finally terminated by giving its lowest fasciocutaneous perforator between the distal tendinous part of VL and RF.

Yamada et al. (2014) conducted a study on 38 cadaveric lower limbs and found that the anterolateral thigh flap received 1-7 perforators from the DB of the LCFA; 17.9% of which were fasciocutaneous and 82.1% were musculocutaneous through VL. Yu et al. (2004) developed a system to classify them according to their remoteness from the ASIS into A, most proximal; B, middle, and C, most distal.

In the present study, the squares equivalent to the classical ALTF are 2 and 3 along with the lowest part of square 1 at the distal end of the TFL muscle. In these squares, the DB of the LCFA provided 2-10 perforators (7.76 ± 1.61), 29.1% of which were fasciocutaneous and 70.8% were musculocutaneous. The fasciocutaneous ones arose from the upper and lower ends of DB of the LCFA, while the musculocutaneous were present in the middle along most of the course of the artery. The most proximal fasciocutaneous perforators arose from the OB of DB of the LCFA in 26.6% of cases, and from the start of the DB of the LCFA in 100 % of limbs. Using Yu et al classification, all the perforators in this region could be divided into A: most proximal with a mean distance of 16.5 ± 0.5 cm, B: middle with a mean distance of 25.47±1 cm, and C: most distal with a mean distance of 29.26 ± 1.6 cm away from the ASIS.

There was considerable variation in the number of perforators identified in the ALT free flap. Two cadaver studies reported eight perforators in the explored thighs (Choi et al. 2007; Malhotra et al, 2008). Hsieh et al. (2021) conducted a study on thirty-seven patients undergoing subfacial anterolateral thigh flap, and reported an average of 3.1 perforators found on each thigh. With other clinical studies, the incidence of no perforator being found ranges from 0.89 to 5.4 percent (Lakhiani et al., 2012). In a systematic review by Lakhiani et al. (2012), where they ran an aggregate analysis of 2895 cases from all the published clinical, cadaveric, and angiographic studies, the overall incidence of perforator absence was found to be 1.8 percent. Furthermore, in another systematic review published by Smith et al. (2017) the mean number of perforators was found to be 2.1 in clinical studies and 2.7 in cadaveric studies.

Zachara et al. (2013) divided the perforators in the ALTF according to their mean external diameter into thin (less than 0.5 mm), medium (0.5-1 mm) and thick (more than 1 mm). They found in their study that 35% of the perforators were thin, 35% were medium and 29.2% were thick.

In this study, it was found that most of the perforators of the DB of the LCFA were medium-sized with a percentage of 62.2%, while 21.25 % were thin and lastly 16.3% were thick. Abdel Hamid (1994) and Cormack and Lamberty (1985) agreed that the higher perforators are thicker, and the caliber decreases from above downwards. This study conforms to this finding.

This study found that the DB of the LCFA exhibits a segmental pattern of branching, giving off its perforators at more or less fixed distances tuntil its termination. This segmentation was exploited in reconstructive surgery by Hallock (2009), who first introduced the concept of chimeric flaps. He defined this flap as that which consists of multiple independent flaps, each having an independent vascular supply, with all pedicles linked to a common source parent vessel. He stated that the ALTF is the prototype of this flap, as it can be split into smaller segments that have independent vascular supply, yet attached to one source artery; the DB of the LCFA. Chou et al.(2006) reported that two fasciocutaneous flaps associated with independent skin vessels could be reliably harvested from the same descending branch of the LCFA for the simultaneous reconstruction of two separate defects.

In addition to the DB of the LCFA, Yamada et al. (2014) stated that the anterolateral thigh is also supplied distally by a fasciocutaneous branch of the SLGA. Its branches reached as high as the midthigh point (Yamada et al., 2014). Gstoettner et al. (2019) stated that its furthest branch entered the skin at 8.8 cm above the knee joint line.

The present study found that the SLGA provided a fasciocutaneous perforator in all cases. It pierced the deep fascia at a mean distance of 7.7±0.5 cm above the LTC to continue forwards and medially. This artery provided excellent parameters in terms of length and caliber. Its mean length was 9.3±0.54 cm and its mean diameter was 2.1±0.06 mm. This long pedicle provides considerable length to the equivalent flap, which can be further extended distally to cover the upper leg defects. This flap is downward extended ALTF (DEALTF).

From the previous description of the perforators of the DB of the LCFA and the SLGA, the design of the chimeric ALTF could be illustrated (Fig. 8).

Of the very first who illustrated the definitive anatomy and clinical use of the TFL flap were Hill et al. (1978), who described it in their study as a pedicled rotation flap based on the TB of the LCFA. Little and Lyons (1983), on the other hand, stated that the main pedicle to the TFL muscle is the AB. Zufferey et al. (1988) added that the distal part of the muscle is supplied by musculocutaneous perforators that come off directly from the PFA. That is why authors like Kalandar and Morris (2019) reported that there is some confusion regarding its arterial supply, and found in their study that the muscle is mostly dependent on the AB of LCFA, and there was only one case where it presented dual blood supply from the AB and TB of LCFA. They all agreed that the skin over the TFL is supplied by musculocutaneous perforators from the underlying muscular artery. Zufferey et al. (1988) added that the skin also receives fasciocutaneous perforators from the DB.

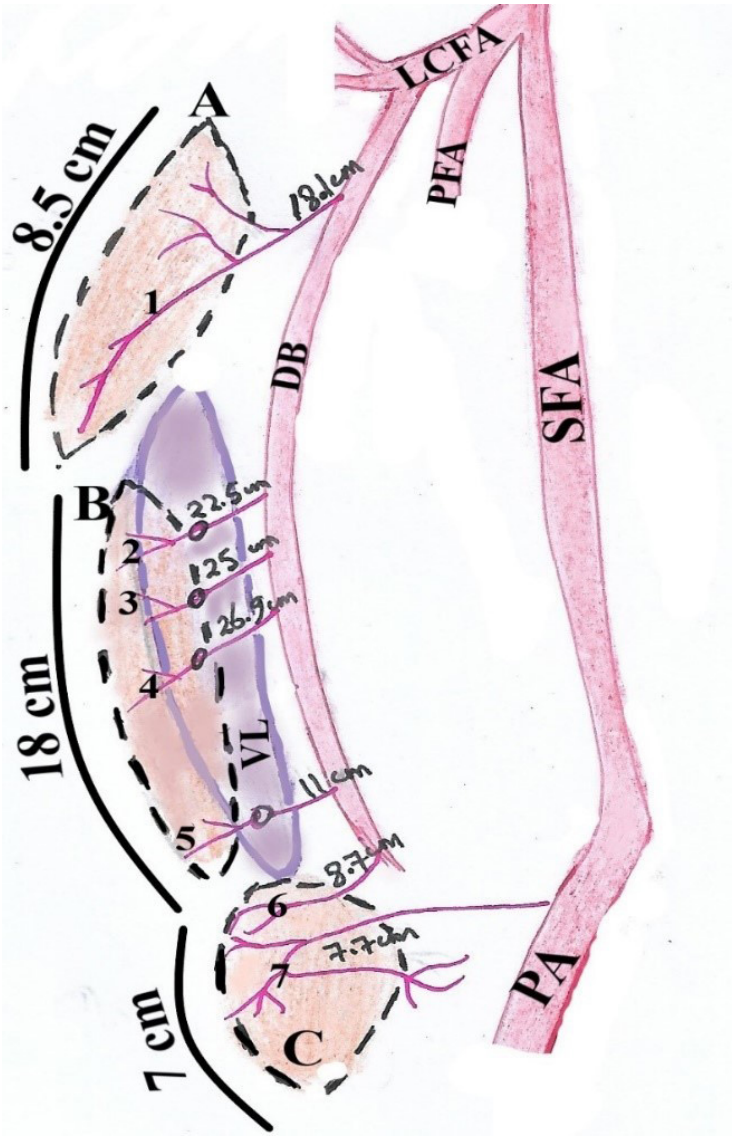

Fig. 8.- A diagrammatic picture of the possible design of the chimeric anterolateral thigh flap (ALTF) of the right thigh. Three possible ALTFs (A, B and C) can be raised. Flap A can be raised on the first fasciocutaneous perforator (1) of the descending branch (DB) of lateral circumflex femoral artery (LCFA). It took origin at a mean distance of 18.1 cm distal to the ASIS. The flap is up to 8.5 cm in length. Flap B can be raised on the musculocutaneous perforators (2, 3, 4, and 5) of the DB which took origin from it at mean distances of 22.5, 25, 26.9 cm from the ASIS and the lowest at a mean distance of 11 cm from the lateral tibial condyle (LTC). This flap can reach up to 18 cm in length. Flap C can be raised on the last fasciocutaneous perforator (6) of the DB which took origin at mean distance of 8.7 cm above the LTC, and on the lateral fasciocutaneous perforator (7) of the popliteal artery (PA) which took origin at a mean distance of 7.7 cm above the LTC. This flap can reach up to 7 cm in length. PFA: Profunda femoris artery, SFA: Superficial femoral artery.

CONCLUSION

After the accomplishment of the present work, one can conclude that: The anterolateral thigh skin is richly supplied by a mixture of the three types of perforators. The segmental nature of the perforators arising from the DB of the LCFA together with the superbly long course of the artery itself grants the famous ALTF its versatility as a chimeric flap. The highest fasciocutaneous perforator of the DB of the LCFA, which spanned squares 1 and 2, makes it a good choice for either local or free flaps. Its long pedicles warrant better mobility if used as island flap.

REFERENCES

ABDEL HAMID FAM (1994) Detailed anatomical study of musculo-fascio-cutaneous blood supply of the thigh. In: El Kalaa FA, Osman MZ, El Tahan AK (editors). Alexandria: Alex-Uni F.O. *Medicine*. Fathia Ahmed Mohamed Abdel Hamid.

CHAN JC, WARD J, QUONDAMATTEO F, DOCKERY P, KELLY JL (2014) Skin thickness of the anterior, anteromedial, and anterolateral thigh: a cadaveric study for split-skin graft donor sites. *Arch Plast Surg*, 41(6): 673-678.

CHOI SW, PARK JY, HUR MS et al (2007) An anatomic assessment on perforators of the lateral circumflex femoral artery for anterolateral thigh flap. *J Craniofac Surg*, 18(4): 866-871.

CHOU EK, ULUSAL B, ULUSAL A, WEI FC, LIN CH, TSAO CK (2006) Using the descending branch of the lateral femoral circumflex vessel as a source of two independent flaps. *Plastic Reconstr Surg*, 117: 2059-2063.

CORMACK GC, LAMBERTY BGH (1985) The blood supply of thigh skin. *Plast Reconstr Surg*, 75(3): 342-354.

CORMACK GC, LAMBERTY BGH (1994) The arterial anatomy of skin flaps. Edinburgh: Churchill Livingstone.

GEDDES CR, TANG M, YANG D, MORRIS SF (2013) Lower extremity: anatomy of the integument of the lower extremity. Perforator Flaps: Anatomy, Technique & Clinical applications. 2nd ed. Missouri: Quality Medical Publishing, p 667.

GSTOETTNER C, MAYER JA, AMAN M, SALMINGER S, BÜRGER H, HIRTLER L, WENINGER W, ASZMANN OC (2019) Cutaneous angiosome of the chimeric SLGA perforator flap: Anatomical study and clinical considerations. *J Plast Reconstr Aesthet Surg*, 72(7): 1142-1149.

HALLOCK GG (2009) Classification of flaps. In: Wei F-C, Mardini S (editors). *Flaps and Reconstructive Surgery*. Edinburgh: W.B. Saunders, pp 7-15.

HILL H, NAHAI F, VASCONEZ L (1978) The tensor fascia lata myocutaneous free flap. *Plast Reconstr Surg*, 61: 517-522.

HSIEH F, LEOW OQY, CHEONG CF, HUNG SY, TSAO CK (2021) Musculoseptocutaneous perforator of anterolateral thigh flap: a clinical study. *Plastic Reconstr Surg*, 147(1): 103e-110e.

KALANDAR A, MORRIS SF (2019) Three-dimensional vascular anatomical study of the tensor fasciae latae muscle and perforators. J Reconstr Microsurg, 35(6): 389-394.

KIMATA Y, UCHIYAMA K, EBIHARA S, NAKATSUKA T, HARII K (1998) Anatomic variations and technical problems of the anterolateral thigh flap: a report of 74 cases. Plast Reconstr Surg, 102: 1517-1523.

KOSHIMA I, FUKUDA H, YAMAMOTO H, MORIGUCHI T, SOEDA S, OHTA S (1993) Free anterolateral thigh flaps for reconstruction of head and neck defects. *Plast Reconstr Surg*, 92: 421-428.

KOSHIMA I, YAMAMOTO H, HOSODA M, MORIGUCHI T, ORITA Y, NAGAYAMA H (1993) Free combined composite flaps using the lateral circumflex femoral system for repair of massive defects of the head and neck regions. *Plast Reconstr Surg*, 92: 411-420.

LAKHIANI C, LEE MR, SAINT-CYR M (2012) Vascular anatomy of the anterolateral thigh flap: A systematic review. *Plast Reconstr Surg*, 130: 1254-1268.

LANDUYT KV (2006) The anterolateral thigh flap for lower extremity reconstruction. *Semin Plast Surg*, 20(2): 127-132.

LITTLE J, LYONS J (1983) The gluteus medius–tensor fasciae latae flap. *Plast Reconstr Surg*, 71: 366-371.

MALHOTRA K, LIAN TS, CHAKRADEO V (2008) Vascular anatomy of anterolateral thigh flap. *Laryngoscope*, 118(4): 589-592.

MARICEVICH M, BYKOWSKI M, SCHUSTERMAN M, KATZEL E, GIMBEL M (2017) Lateral thigh perforator flap for breast reconstruction: computed tomographic angiography analysis and clinical series. *J Plast Reconstr Aesthet Surg*, 70(5): 577-584.

MATHES SJ, NAHAI F (1997) The evolution of reconstructive surgery. *Semin Plast Surg*, 10: 81-88.

MOHAN A, SAINT-CYR M (2015) Anatomic and physiological fundamentals for autologous breast reconstruction. *Gland Surg*, 4: 116-133.

MORRIS SF, TAYLOR GI (2013) Fundamentals: History of perforator flap surgery. *Perforator Flaps: Anatomy, Technique & Clinical applications*. 2nd ed. Missouri: Quality Medical Publishing: 36.

MORRIS SF, TANG M, ALMUTARI K, GEDDES C, YANG D (2010) The anatomic basis of perforator flaps. *Clin Plastic Surg*, 37(4): 553-570.

PARK SO, CHANG H, IMANISHI N (2018) Anatomic basis for flap thinning. *Arch Plast Surg*, 45(4): 298-303.

SMITH RK, WYKES J, MARTIN DT, NILES N (2017) Perforator variability in the anterolateral thigh free flap: A systematic review. *Surg Radiol Anat*, 39: 779-789.

SONG YG, CHEN GZ, SONG YL (1984) The free thigh flap: a new free flap concept based on the septocutaneous artery. **Br J Plast Surg**, 37(2): 149-159.

STANDRING S (2008) Gray's Anatomy: The Anatomical Basis of Clinical Practice. 40th ed. Spain: Churchill Livingstone Elsevier, pp 1331-1334.

SUCCIO G (2014) Anatomy of lateral femoral circumflex artery perforators in planning of anterolateral thigh flap: utility of CT. Pilot study. *Anat Physiol*, 04.

TERRELL M, ROBERTS W, PRICE CW, SLATER M, LOUKAS M, SCHOBER J (2018) Anatomy of the pedicled anterolateral thigh flap for phalloplasty in transitioning-males. *Clin Anat*, 31(2): 160-168.

TIMMONS M (1985) Landmarks in the anatomical study of the blood supply of the skin. *Br J Plast Surg*, 38: 197-207.

YAMADA S, OKAMOTO H, SEKIYA I, WADA I, KOBAYASHI M, GOTO H, et al (2014) Anatomical basis of distally based anterolateral thigh flap. *J Plast Surg Hand Surg*, 48(3): 197-200.

YU P (2004) Characteristics of the anterolateral thigh flap in a Western population. *Head Neck*, 26: 759-769.

ZACHARA M, DROZDOWSKI P, WYSOCKI M, SIEWIERA I, WOJCICKI P (2013) Anatomical variability of the anterolateral thigh flap perforators between sexes: a cadaveric study. *Eur J Plast Surg*, 36(3): 179-184.

ZUFFEREY J, DOERFL J, KRUPP S (1988) The anatomical basis for delaying the musculocutaneous tensor fascia lata flap with a distal extension. *Eur J Plast Surg*, 11: 109-116.