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Review Article

Mapping of Arterial Perforator to Optimize Lateral Arm Flap Design

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ABSTRACT

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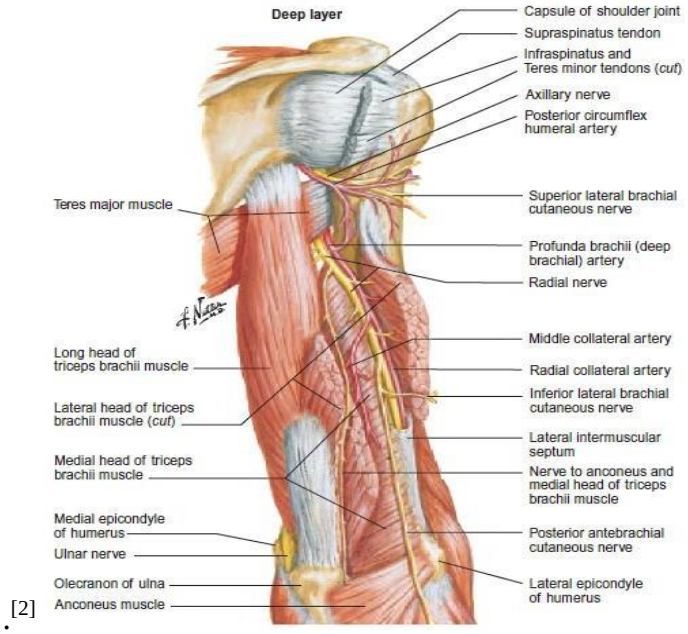
Lateral arm flap (LAF) is aa newly modified versatile flap that could be elevated as a fascial or fasciocutaneous flap; type B pattern of circulation according to Naha's classification. The flap depends on interseptal perforators between lateral arm compartments. It can be used for different resurfacing reconstructive purposes in variable small to medium sized soft defects. Its ability to be elevated as a pedicled flap or a free flap to give it a versatility benefits to resurface many body defects as in the dorsum of the hand, the lower limb, or the head & neck. This flap shows reliable blood supply with ease of dissection and no major vessel sacrifice. It has a thin pliable content and relatively hidden donor site scarring underneath dressed arm. On the other side, the main disadvantages are relatively small diameter of its vasculature, numbness, and pain at lateral arm & upper forearm due to possible injury of lateral cutaneous nerve of arm or Radial nerve injury. This review article aims at discussing, briefly, the lateral arm flap; surgical techniques, indications and contraindications and flap imaging, based on, metanalytic and clinical studies.

1. History and anatomy of Lateral arm flap (LAF)

The lateral arm flap was illustrated by *Song et al. in 1982* for the first time as a free septocutaneous flap that may be modified to correct soft tissue or composite hand defects in different body's areas. [1] Lateral arm flap was presented in the earlier studies that included head and neck reconstruction. The texture and decent color match of the flap make it an a good choice decision in head and facial resurfacing. [2]

Regional anatomy of LAF: The intermuscular septa and the deep fascia divide the arm into anterior and posterior compartments. The lateral and medial intermuscular septa separate the anterior and posterior compartments. The biceps brachii, coracobrachialis, and brachialis muscles are in the anterior compartment. The triceps brachii muscle is in the posterior compartment. The humerus contributes as a pillar to the arm. It is where the lateral head of the triceps and the brachialis muscle

originate. At the midway of the humerus, the deltoid tuberosity is the insertion for the deltoid. This region corresponds to the location of the deep brachial artery and the radial nerve within the spiral groove, where they turn around the humerus as shown in Figure 1



[2]

Figure 1: **Regional anatomy of the lateral arm with vascualar arborization.** [2]

Arterial supply of the flap

Dominant: The posterior radial collateral artery (PRCA) has a length of 6 cm (ranging from 4 to 8 cm) and a diameter of 1.5 mm (ranging from 1 to 3 mm). The PRCA is the major RCA branch that provide nourishment for the flap. It comes from the radial collateral artery at the anterolateral border of the triceps muscle and extends distally via the lateral intermuscular septum between the triceps posteriorly and the brachialis with brachioradialis anteriorly. The overlying skin is supplied by three to five septocutaneous perforators through this intermuscular septum, which ends to be blended with epicondylar and olecranon plexuses (**Ninkovic et al.**, **2001**) **Figure 2.**[3]

First Minor: the anterior radial collateral artery (ARCA) is a 3 cm long (~ 2-6 cm) and 0.8 mm in diameter (~0.5–1.5 mm). *Second Minor:* the recurrent radial artery (RRA) and the interosseous recurrent artery (IRA) are essential for distally pedicled flap with 3 cm length (~ 2-5 cm) and 0.8 mm in diameter (~ 0.5-1.2 mm). [4]

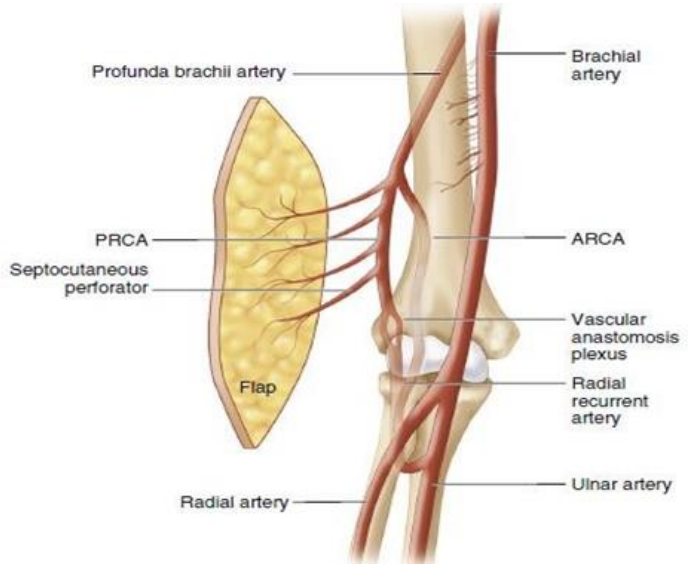


Figure 2: Diaphragmatic picture of lateral arm flap showing ARCA, anterior radial collateral artery; PRCA, posterior radial collateral artery. [4]

Venous drainage of the flap

The primary venous drainage are venae commitantes accompanying the posterior branch of Radial collateral artery. They are 6 cm long (ranging 4–8 cm) and 2.5 mm in diameter (ranging 1.5–3 mm). They are two in (75%) of cases and one in (25%) of cases. [5]

Secondary venous drainage includes Cephalic vein, 20 cm in length and 6 mm in diameter (~4 - 10 mm). To improve drainage, the cephalic vein or minor branches might be incorporated in the anterior portion of the flap.[5]

Flap innervation

The lower lateral brachial cutaneous nerve is a main sensory branch suppling the LAF's skin area (figure 1). The posterior antebrachial cutaneous nerve innervates more skin region distal to the lateral epicondyle, which is describes as an extended LAF. [5]

Lateral Arm Flap Modifications

Extended lateral arm flap (ELAF)

This modification gives more length that can reach longer than the classic LAF. This is achieved by expanding the skin island territory either towards the epicondylar area or furthermore to the dorsal upper forearm. The axis of forearm skin island spans between both the processes styloideus radii and the lateral epicondyle. [6]

Reverse flap

This modification shall make flap's vascular supply dependends on the epicondylar and olecranon plexusi, which are fed by the interosseous recurrent artery (IRA) as well as the radial recurrent artery, respectively (RRA). The reverse pedicled flap is collected in the same way as the free flap, however the distal anastomosis is preserved, and the artery is cut proximally.[6]

Fascial and adipofascial LAF

The fascial LAF/ELAF is a thin and elastic tissue that molds nicely to the contours of the digits, and its inferior surface offers a sliding surface for tendons. Skin flaps are lifted just above fascia after a curvilinear skin incision overlaying the lateral intermuscular septum axis of the upper arm or proximal forearm. Preferably leave a thin layer of fat above the fascia, elevating the flap like a fascia flap. Furthermore, the amount of fat to be incorporated with the flap is governed by the requirements at the recipient location. [6]

Suprafacial LAF modification

The supra-fascial lateral arm flap harvest has the advantages of reducing the donor-site morbidity, as well as increase flap pliability. Suprafascial dissection is performed from the back until the lateral intermuscular septum is approached. The Septocutaneous perforators from the PRCA are distinguished in the superficial plane at the location of initially made skin marks. The anterior flap edge is dissected in the same way. Once the lateral intermuscular septum is identified, the fascia is incised on both sides and the pedicle are elevated. The remained fascia is closed after flap harvest. [6]

Osteocutaneous lateral arm flap

An osteocutaneous lateral arm flap can be constructed if a well vascularized bone graft is necessary. The flap can be employed to collect the humerus's lateral supracondylar ridge. The method is comparable to the typical flap illustration. [6]

Combined musculotendinous and fasciocutaneous LAF.

The PRCA has vascular attachments to the triceps lateral head. As a result, the LAF/ELAF can be extracted along with a muscle fragment for greater flap bulk. A vascularized triceps tendon section may also be added for tendon transplantation. A 10 X 2 cm lateral section of tendon with muscular tissue is raised after visualization

of the distal lateral head of the triceps. [6]

Neurosensory flap

For a neurosensory flap concept, the PACN and LBCN may be incorporated with the flap. The LBCN reaches the cutaneous area of the flap at the position of the deltoid insertion and is visible at the skin island's proximal border. For appropriate nerve length to create a neurosensory flap, proximal dissection of this nerve is essential. In the distal portion of the upper arm, the PACN penetrates the deep fascia somewhat anterior to the intermuscular septum and runs superficial to the brachioradialis muscle. [6]

2. Surgical technique for L.A.F elevation.

Before surgery, the surgeon must confirm that there has been no recent trauma or surgical intervention in the donor region that might jeopardize the LAF/vascular ELAF's supply. In situations of trauma, a Doppler sonography or, in extremely unusual circumstances, an angiography (CT angiogram) must be performed to evaluate the blood flow. Extensive local scarring may exclude the use of LAF as a reconstructive option [7]

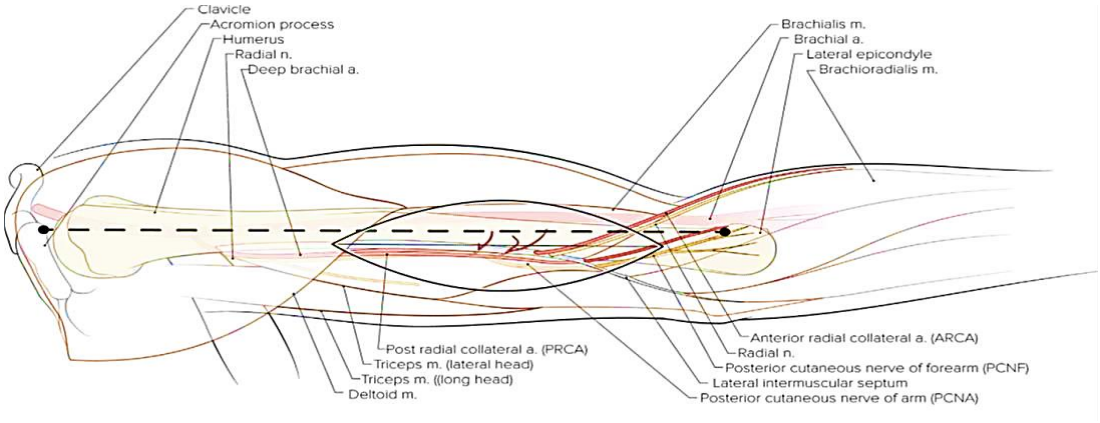


Figure 3: Topographical anatomy of the lateral arm donor site. The axis of the posterior radial collateral artery is 1 cm posterior to a line drawn from the acromioclavicular joint to the lateral epicondyle. [7]

Elevation Technique

The flap size can range from 7 to 12 cm in length and 5 to 6 cm in width. The skin paddle has a maximum width of 7 cm and encloses the biceps and brachialis muscles anteriorly as well as the lateral head of the triceps muscle posterior to the septum. The skin island's primary axis crosses the septum between both the brachialis and triceps

muscles (lateral intermuscular septum). It is a line traced from the lateral epicondyle to the insertion of the deltoid muscle. The flap's distal pole is drawn 1- 2 cm proximal to the epicondyle, while the proximal pole is drawn 4-6 cm underneath the deltoid insertion. [8[An incision is performed on the flap's lateral side. Subfascial dissection is undertaken and continues anteriorly up to previously marked site of the lateral intermuscular septum is reached or cutaneous perforators are identified. [9] Flap lifting is resumed at the flap's anterior boundary, where the brachial fascia is discovered and incised. The flap is now undermined in the subfascial plane until it reaches the anterior portion of the lateral intermuscular septum. [10] The dissection can also be prolonged proximally between both the lateral and long heads of the triceps muscle to stretch the pedicle up to the brachial artery. These muscles must be divided to access the takeoff of the profunda brachii artery from the brachial artery for more dissection. It is critical to protect the radial nerve branches to the triceps muscle while performing this approach.[11]

Figure 4: **a**. Incision of the skin and exposure of the intermuscular septum including the pedicle. **b**; Release of the flap up to the lateral epicondyle. **c.** Preparation of the pedicle (radial collateral artery) and exposure of the posterior antebrachial cutaneous nerve, **d.** Removed flap with pedicle and posterior antebrachial cutaneous nerve.[11]

Indications & contraindications of lateral arm flap:

Indication

In case, skin grafting, or local flap coverage are not viable options owing to the necessities of the lesion, the LAF/ELAF is indicated. It is the most flexible free fasciocutaneous flap for difficult reconstructions of the head, neck, upper and lower extremities due to its free LAF/adaptability. [12] Three-dimensional defects, defects with exposed anatomical systems (such as bone, tendon, or nerve) after aggressive tumor excision, post-burn scars, ulcers or unstable scars, as well as the necessity for a moving layer for sufficient coverage are all possible indications. Larger lesions or severe post-traumatic defects that need vascularized bone, tendon, or nerve grafts might benefit from the LAF/ELAF. In all indications, the ELAF may substitute the radial forearm flap (RFF) with far less donorsite complications than the RFF. [13]

Pedicled LAF/ELAF

Soft tissue defects of the shoulder and axilla

The pedicled LAF/ELAF could be turned anteriorly or posteriorly toward the shoulder or axilla. The posterior path is certainly shorter because of the anatomical course of the PRCA. Prolonged vascular pedicle dissection can enhance the rotational arc of the pedicled LAF/ELAF. The pedicle of the flap can be severed around the juncture of both the profunda brachii artery and the brachial artery. To do this, the lateral as well as the long heads of the triceps can be separated, or the triceps muscular fibers can be partly freed from their connection to the humerus. The profunda brachii can then be dissected backwards all the way up to the region where it exits from the brachial artery in the spiral groove. This dissection will expand the length of the pedicle by about 7-8 cm. Because it has a longer pedicle, the ELAF extends the arc of rotation even more. [13]

Soft Tissue Defects of The Elbow Region

The reverse LAF can be inserted into the elbow region either in an ulnar or radial orientation. The LAF flap takes less time throughout surgery and a reduced hospital stay for elbow reconstruction. [13]

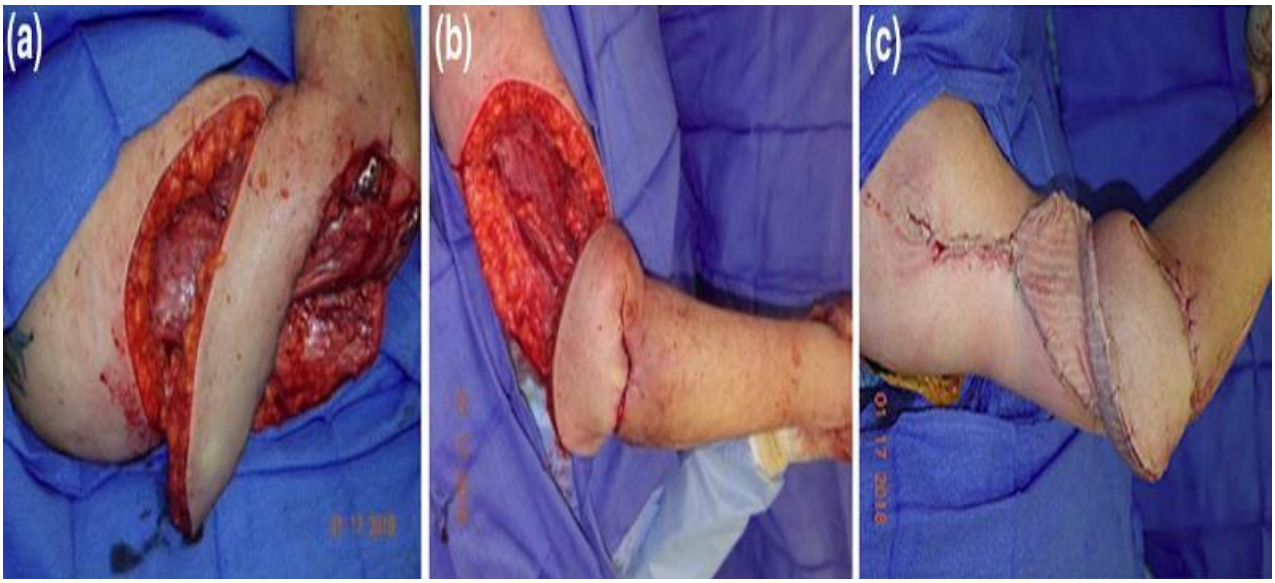


Figure 5: Intraoperative views showing 52-year-old patient developed an infection of distal humerus after an osteosynthesis with two plates due to distal humerus fracture. A reverse lateral forearm flap distally based on the interosseous recurrent artery was performed. After thorough surgical. [13]

Free LAF/ELAF

Head And Neck

In the area of the neck and head (Kang et al., 2018) This flap can also be utilized to repair partial non-circumferential hypo- pharyngeal or upper esophageal abnormalities, contour deformity deficits (acquired or congenital), and all types of intraoral deformities.[14]

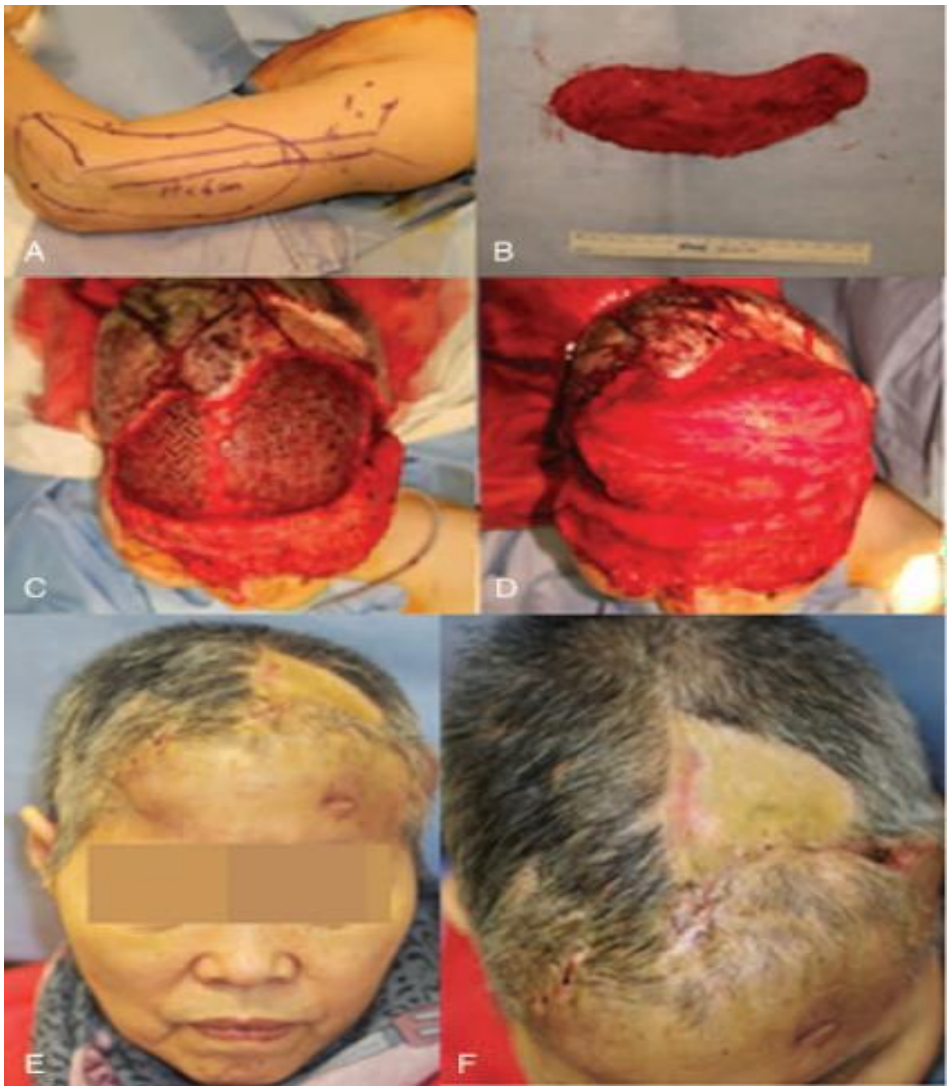


Figure 8: (A, B) Pre-operative design of the extended type free lateral arm flap.(C, D) Intraoperative findings of titanium mesh implant and flap coverage. (E, F) Post-operative findings after 8weeks.[14]

Upper and Lower Extremities

The rebuilding is carried out in the same manner as the head and neck region. Given the common deficiencies in this area, bone, muscle, tendon, or nerve tissue may need to be included more frequently. When there is a little injury and a small zone of harm, this flap can be used. It is appropriate for those who have high functional needs and require a tiny fasciocutaneous flap to protect important components. When thin cover is needed or a rolling surface for tissue excursion is needed, the free fascial variety of the LAF is recommended. [15]

Atypical Indications for LAF

Penile reconstruction with a free fasciocutaneous LAF/ELAF The urethra is the most significant aspect of this restoration. The urethra is lined with a 3 cm broad longitudinal bar. A tiny region adjacent to this bar is de-epithelialized on both ends. Stitched back together, the deepithelialized portions produce an epithelialized tube. The lateral tissue to the de-epithelialized parts is then folded around the neo-urethra to produce the penis. The shaped LAF is transported to the perineum and fastened to the pubic symphysis periosteum. [16]

Contraindications for LAF:

Few contraindicated use of LAF can be due to unknown reliable perforator especially at area trauma or surgical zones of lateral arm. The LAF is less suited for defects broader than 5-6 cm, as skin grafting may be required. For some less demanding and quicker reconstructive operations may be considered in the case of a patient with major comorbidities or a poor overall health state. Also it is relatively contraindicated in hair bearing areas of face, neck or glabrous skin areas as palm of the hand. It is not advised to harvest a flap in markedly obese patient with high BMI, which may result in a bulky flap with noticeable scar at the donor site. [16]

3. Advantages and disadvantages of lateral arm flap

Advantages

Since the LAF/ELAF comprises a terminal branch of the PBA, there is no danger to the vascular supply of the hand during raising. Dissection is comfortable with the patient in both the supine and prone positions. In senior individuals, donor site complications are modest, with typically direct closure up to a breadth of 8 cm. The unique vascular plexus around elbow area offers for tremendous design flexibility. [17]

Disadvantages

The donor site problems include lateral epicondylar discomfort, hyperesthesia of the proximal lateral forearm skin due to damage to the forearm's posterior cutaneous nerve following flap lifting, transient radial nerve palsy, and restricted range of movement. This region of hyposensibility, however, is greatly diminished after 6 months due to ingrowth of nearby cutaneous nerves. [17]

Complications of Lateral Arm Flap

The issues with LAF/ELAF translocation are related to donor site complication. Lateral epicondylar discomfort and oversensitive scars relate to patient dissatisfaction in 19.4% and 17% of Graham et al datasets respectively. The use of a split thickness skin transplant to cover the donor location will almost certainly result in an unattractive look. (Graham et al., 1992). The most common cause of lateral epicondylar discomfort is initial closure at the donor site. This might be due to a close wound closure or the presence of the epicondylar periosteum in the flap. Some elbow movement limitation may also occur. [17]

4. Flap Mapping

Radial artery was used for the radial forearm flap and the thoracodorsal arteries were used for the latissimus dorsi flap in the first generation of axial pattern flaps. Despite being groundbreaking at the time, the harvest of these flaps is today regarded as being very simple due to their consistent morphology. [18]

Hand-Held Doppler Sonography (HHD)

A Doppler probe in the shape of a pencil uses reflected ultrasound to send out and identify moving erythrocytes. Varied probes with various frequencies can be utilized, depending on the depth and diameter of the vessels to be studied. The peak sensitivity of the two most used frequencies, 8 and 10 MHz, is only 20 and 15 mm, respectively.[18]

Color Duplex Sonography (CDS)

The same operational theory underlies CDS and HHD. The physical concept of a direct correlation between the recorded. Doppler frequency shifts and blood-flow velocity allows for the detection of blood flow in arteries. Additionally, in color duplex mode, various blood stream directions and velocities can be shown on a screen. Additionally, due of its real-life dynamics, it is less replicable. Another drawback of CDS and HHD in compared to CTA, MRA, and DSA is that neither can reproduce a 2D or 3D image of the entire vascular architecture, which the surgeon can use forflap design or flap elevation. [19]

Colored Duplex Sonography in LAF

Radiologic examination using "Colored Doppler sonography" to assess and map perforator diameters and places in relation to fixed points, namely the deltoid insertion and the lateral epicondyle of the humerus, with illustration of radiologic features of the radial collateral artery course and its visible branche.[19]

Digital Subtraction Angiography (DSA)

Traditional angiography involves injecting an iodine containing contrast material into the artery while taking X-rays. In DSA, the pre-contrast mask X-ray is digitally deleted from these contrast-enhanced images to show the vascular structure. This study method produces 2D images, therefore it must often be carried out in two directions. The intraluminal vascular architecture imaging and information regarding atherosclerotic alterations are two of the stated benefits of DSA. [19]

Computed Tomography Angiography (CTA)

CTA combines the use of X-rays with computerized 3D analysis of the images. The number of detector rows decide how fast a scan can be performed and to what extent details can be revealed. A great variety of CT scanners and software is currently available, making a comparison of the results of various studies difficult. The number of multi-detector rows used in different studies varies to enabling the generation of slices of approximately 1 mm or thinner, depending on the CT scanner used. [20]

Magnetic Resonance Angiography (MRA)

During MRA imaging, a powerful magnetic field is used to align the hydrogen atoms' nuclear magnetization. Radiofrequency pulses are used to tilt the alignment of the hydrogen nuclei away from the prevailing magnetic field, which causes the hydrogen nuclei to generate a radio-frequency signal that can be detected by the scanner. This is then subjected to computer processing, which yields detailed images of virtually all organs, soft tissues, bones, and other structures. After receiving an injection of a paramagnetic contrast agent, the vessels get better (gadolinium). [20]

Conclusion

Lateral arm flap is a versatile fasciocutaneous flap that can be used as a pedicled flap based on radial recurrent artery or as a free flap for medium sized defect. The customized modification of the Lateral arm flap can fit for different reconstructive purposes as in extended type, propeller, reversed flow, free flap, sensory flap, or fascio-Osseo-cutaneous type. The preoperative Imaging of LAF perforators is a reliable method for perforators allocation and subsequently flap design. This help to cut short time of surgical procedure. LAF can be a workhorse flap in different reconstructive purposes in extremities, head and neck. It is comparable to other flaps although it leaves unsightly scar at lateral arm that should be discussed with the patient before surgery.

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