LATERAL ARM FLAP

The Lateral arm flap was first described by Song in 1982[73]. Its reliability and constant anatomy encouraged more surgeons to explore its anatomy and surgical indications[17,40,69]. Since then, this flap has shown itself as a highly versatile flap with many variations for different reconstructive challenges:

- Adipofascial flap[40]. Basically it is the same flap where only subcutaneous tissue is preserved. though it can be thinned superficially to be adapted to the requirement of the recipient site. A flap measuring up to 9 cm by 12 cm can be safely elevated[68].
- Musculofascial flap. The close connection, via terminal vessels, between the main artery and Triceps muscle, enables the flap to be transferred, with a portion of the lateral head of the Triceps[32].
- Vascularized Triceps Tendon flap. Musculocutaneous perforators from the posterior radial collateral artery, that come through the lateral head of the muscle vascularize a segment of Triceps tendon. Harvesting a segment of the muscle ensures that a segment of Triceps tendon, measuring up to 10 cm can be harvested and transferred with the flap[1].
- Osteocutaneous flap. The posterior radial collateral artery gives off one or two periosteal branches to the humerus[33,36,77] at approximately 2 to 7 cm proximal to the lateral epicondyle[33]. A segment of 10 to 15 cm in length, by 1 to 1.5 in width can be harvested over this area and used to repair small to medium size defects at the phalanges, metacarpals and metatarsals[68], or can even be used for mandibular reconstruction[51,77].
- Neurocutaneous sensory flap. The lower lateral cutaneous nerve provides sensation to the skin over the lateral aspect of the arm and subsequently to the Lateral arm flap. It runs subcutaneously and has to be preserved when performing the initial subcutaneous incision. A segment of up to 10cm can be harvested with the flap[11,35].
- Split flap. The cutaneous-subcutaneous paddle of this flap is usually nourished by two separated perforators that vascularize two different parts of the flap; and as long as the main vessel is preserved, both perforators and their territories can be split into two and be used to repair through-and through defects in the oral cavity[54].

When transferred with the posterior cutaneous nerve, it will leave an area of hypoesthesia or anesthesia over the proximal radial skin in the forearm.

Indications

As a highly versatile flap, it has been widely used. For defects on neighbouring areas (axilla, coracoid area, elbow, proximal forearm) it can be used as a local pedicle perforator flap, distally or proximally based[18,77]. As mentioned previously, this flap is considered a compound flap that can include: skin, subcutaneous tissue, sensitive nerves, muscle, tendon and bone. It can therefore be used to repair a great variety of defects at the elbow[18,71,77], hand[54,68], forearm[66], face[69], oral cavity and tongue[51], ear and nose coverage[11], or to repair limited bony defects such as for the hand or mandible. As a flap that is capable of transfering a limited segment of tendon, it has also been used to repair tendon defects at the hand, the Achilles tendon or the Tibialis anterior. As an osteocutaneous flap it can be used to repair medium-sized bony defects of the phalanges, metacarpals and metatarsals [68].

Vascularization and anatomy

Vascularization of this flap has been extensively studied and described[7,40,84]. The territory where the flap is harvested from is vascularized by septal arteries arising from the *Posterior Radial collateral artery* (PRCA), alternatively known as *Posterior descending branch of the Brachial artery* (PDBBA).

The PRCA runs within the intermuscular septum, between the brachialis and brachioradialis muscles anteriorly and the triceps brachii muscle posteriorly, and is intimately attached to the lateral border of the humerus, where it gives off periosteal and muscular branches and septocutaneous perforators. The most proximal perforator is closely related to the posterior cutaneous nerve of the forearm.

The PRCA courses distally, to anastomose with the *Radial recurrent artery* and posteriorly to the lateral epicondyle of the humerus, with the *Posterior interosseous recurrent artery.*

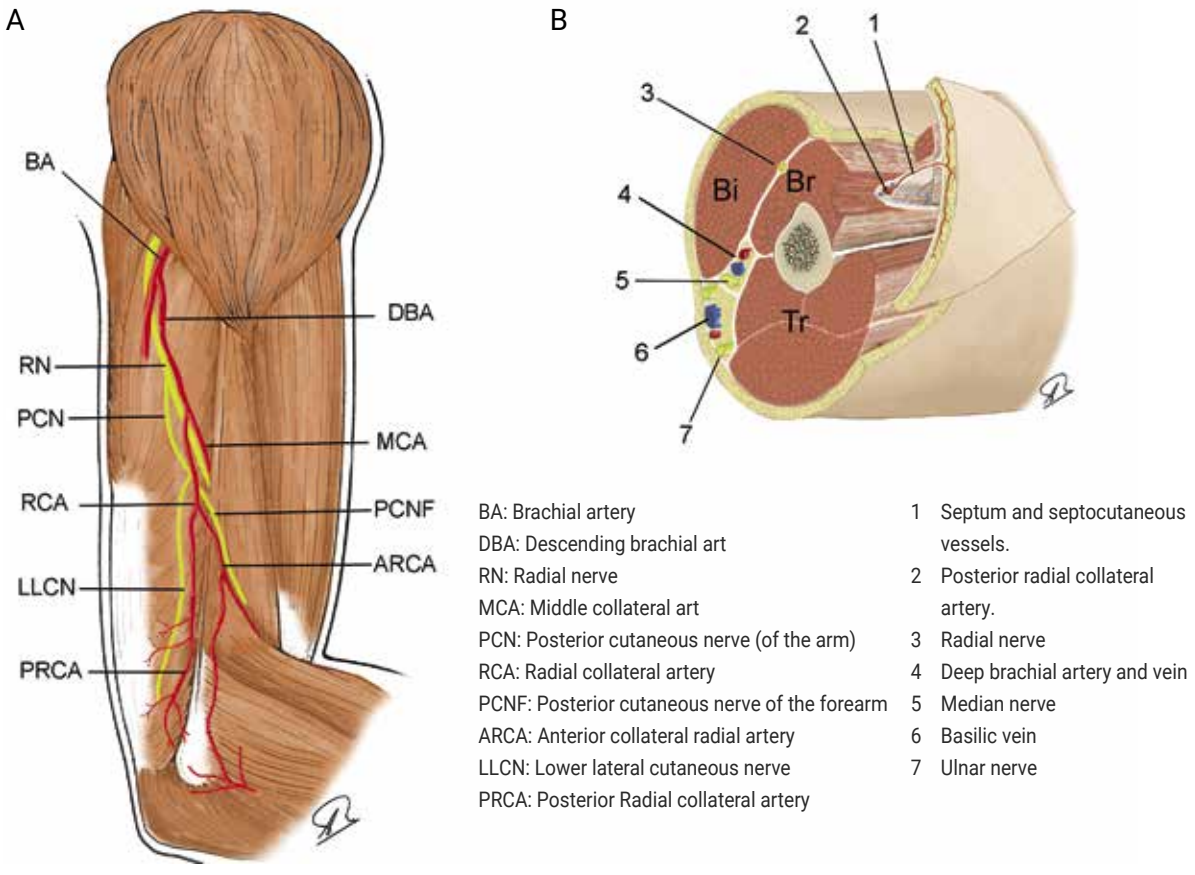


Figure 6.30. Vascularization of the arm. A) Nerves and arteries are seen traced over the arm musculature. B) Section of the left arm and the Lateral arm flap (partly elevated).

The descending branches from the *Brachial artery,* the *Posterior radial collateral artery* (PRCA), the *Superior and Inferior ulnar collateral arteries* are those which will finally give the branches for the vascular network at the elbow. The PRCA with the *Radial recurrent artery* will be the responsible for the vascularization of the reverse lateral arm flap via the (posterior) Interosseous recurrent artery.

Markings

Two references are first marked out at the acromion and the epicondyle. A dotted line is traced between these two points, and will correspond to the intermuscular septum. Lateral to this line lies the axis of the Lateral arm flap. The flap is outlined as an ellipse around the central axis that represents the lateral intermuscular septum (in which the *Posterior radial collateral artery* courses). The ellipse can be outlined on the distal two thirds of the arm. The flap dimension can vary from 8 x 10 cm to 15 x 14 cm according to Katsaros et all.[40], but if the deep fascial plexus is included in the flap, the proximally based lateral arm flap can be extended up to 10-12 cm more, over the elbow[7].

Elevation

Common to Proximal and Distally based flaps: Surgery is initiated under controlled ischemia with a high position tourniquet. Elevation of the flap starts with a full thickness incision along the posterior border of the flap, deepened to expose the triceps. The flap is elevated subfascially until the intermuscular septum (where the PRCA

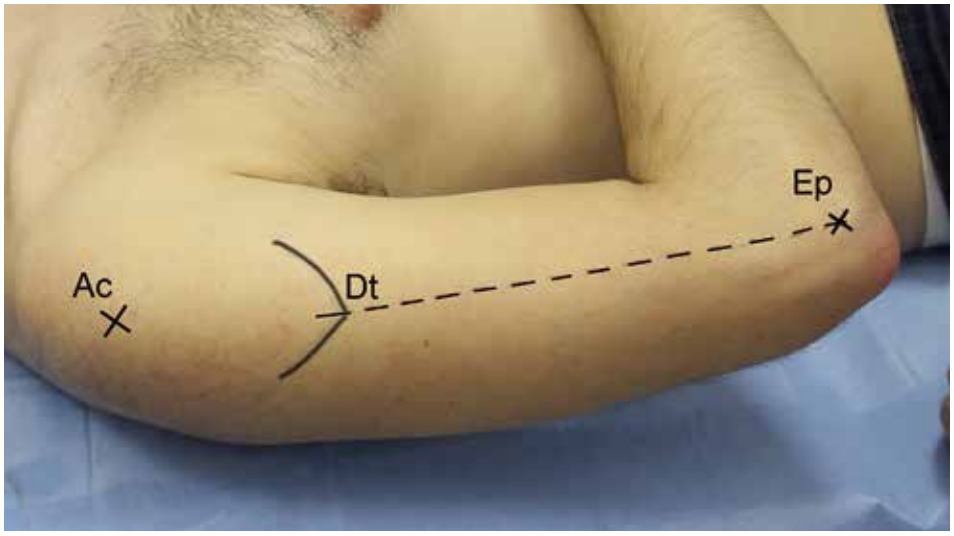


Figure 6.31. Main references for the Lateral arm flap: Alternatively, the Acromion (Ac) or the most distal point of the deltoid insertion (Dt,) can be used, both as the upper reference. Distal reference is marked over the epicondyle (Ep). A line is traced between both points.

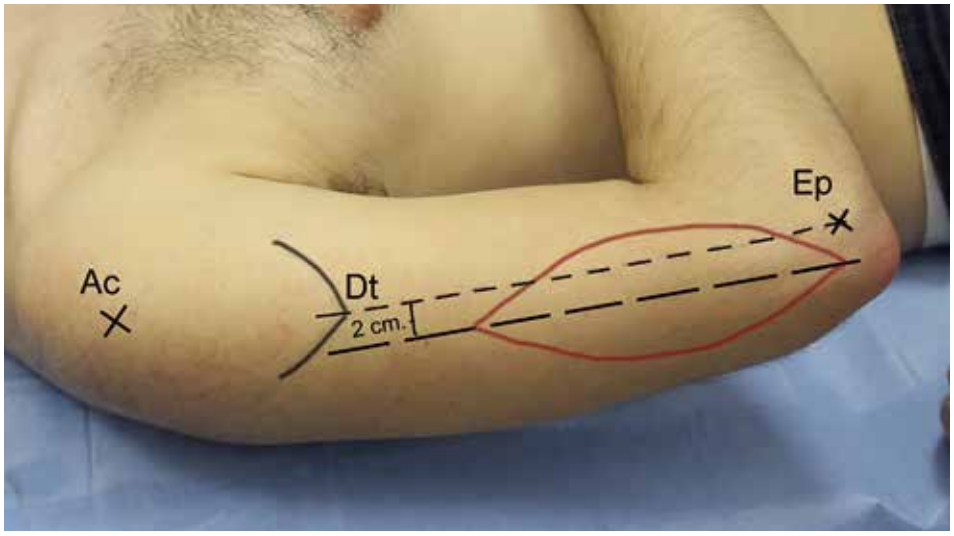


Figure 6.32. At approximately 2 cm posteriorly to the Dt-Ep line, a parallel line is drawn. This line represents the position of the lateral intermuscular septum and the axis of the flap. The skin paddle is designed as an ellipse. The distal pole is located 1 or 2 cm proximal to the epicondyle and its proximal pole 4-6 cm distal to the Deltoid insertion. The width of the flap will depend on the recipient site's defect but also, if it is intended to primarily repair the donor area. Usually any flap measuring no more than 7 cm width will facilitate primary repair.

runs) is reached (Fig. 6.34a). The vascular pedicle is located at the deepest part of the septum, very close to the humerus bone. Once dissection of the posterior part is completed (6.34b), the anterior flap is incised deep into the fascia, leaving it attached to the flap and progressing subfascially, until the septum is reached (Fig 6.35a). At the anterior aspect of the Septum, the Brachioradialis muscle has some insertions that should be carefully divided by sharp dissection to avoid injury to the vascular pedicle (Fig. 6.35a). A muscular cuff is better left attached to the septum, to ensure proper vascularization, especially if a bone fragment will be raised with the flap. Once the flap has been freed from the intermuscular septum and the vascular pedicle is identified, the septum is liberated from the humerus.

For large distally based flaps, it is not necessary to go any further proximally, and the pedicle can then be isolated and ligated on the upper limit of the flap.

For proximally based flaps: From the posterior aspect, over the triceps muscle and tendon, dissection continues exposing the septum. This plane of dissection is easier as, unlike the Brachioradialis, there are not muscular fibers from the triceps attached to either the posterior aspect of the lateral intermuscular septum or the deep fascia. Every small vessel has to be carefully coagulated or ligated (Fig. 6.35b). The distal pedicle can then be divided, distal to the bifurcation of the radial collateral artery, into its posterior and anterior branch-

es. Proximal dissection continues upwards to obtain a longer pedicle if necessary. The radial nerve has to be identified, as well as the cutaneous collateral nerve, and both are isolated from the pedicle. The radial nerve lies anterior to the *Posterior radial collateral artery* before coursing between the brachialis and brachioradialis muscles. (Fig. 6.36-37). The Posterior cutaneous nerve (PCN) originates from the radial nerve, inferiorly to the lower cutaneous nerve within the spiral groove. It pierces the lateral intermuscular septum positioning itself anterior to it, running with the RCA before piercing the triceps muscle to reach the skin. Preservation of this nerve is important to avoid hypoesthesia or anesthesia on the proximal dorsal forearm. The Lower lateral cutaneous nerve branching off the radial nerve, proximally to the Posterior cutaneous nerve (PCN) within the spiral groove, innervates the flap and should be transferred with it, if a sensate flap is needed. Once distal branches for muscles are divided (fig. 6.37b) and nerves, especially the radial nerve, are left well protected, the flap is ready to be transposed. A proximal incision can be made to facilitate upward rotation.

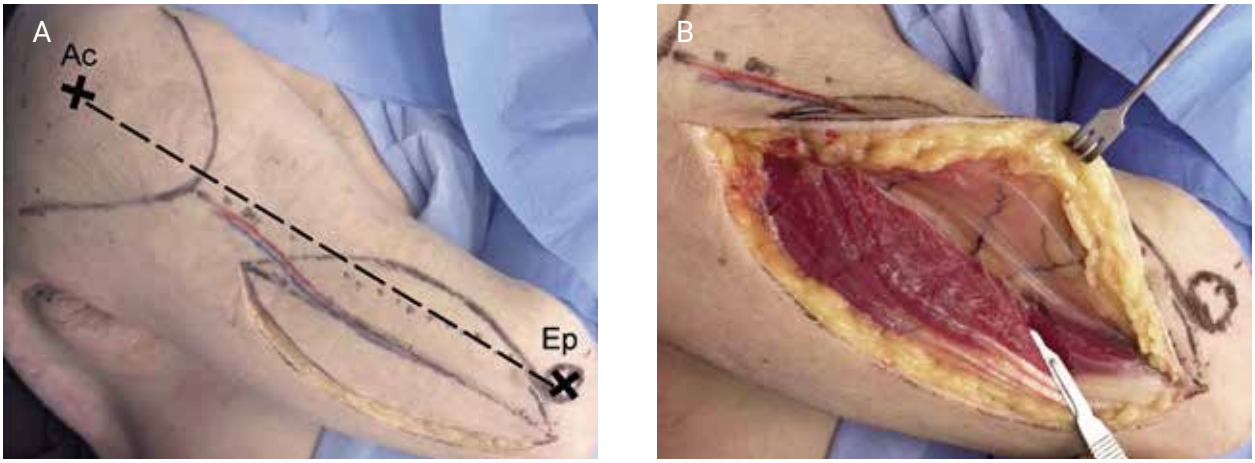


Figure 6.33. Markings. A) Ac: Acromion, Ep: Epicondyle. Dotted line indicates the reference from where the lateral septum of the arm can be localized and where the axis of the flap is marked out. The elliptical cutaneous paddle is outlined over this axis. B) Posterior incision is first performed deep into the fascia, which is left included in the flap. Elevation continues up to the base of the intermuscular septum, where perforator vessels are seen emerging from the Posterior radial collateral artery. This septum separates the Triceps from the Brachialis muscle.

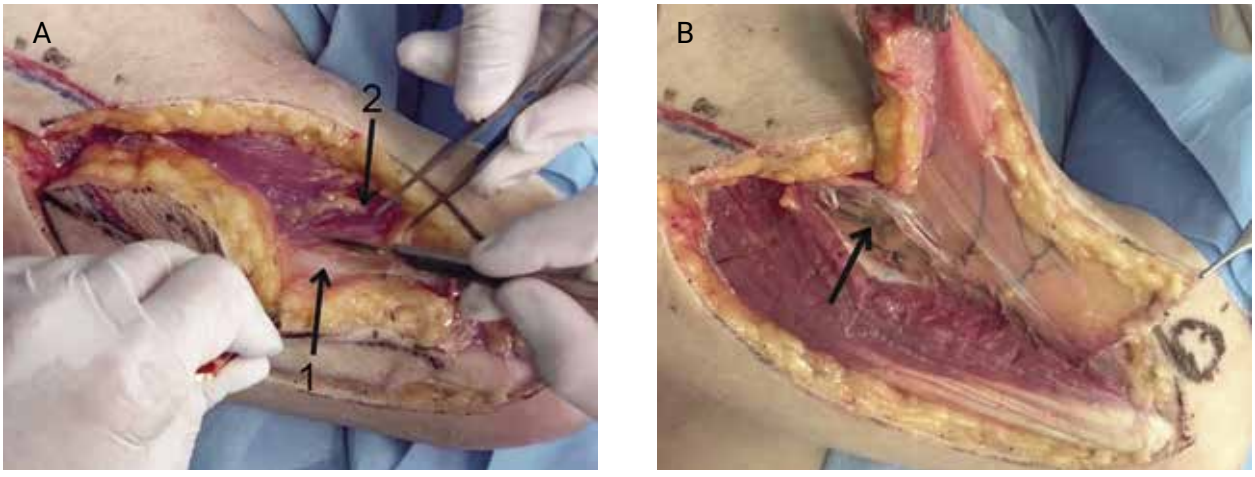


Figure 6.34. A) On the anterior aspect of the arm the incision is equally performed deep into the brachial fascia, until the anterior aspect of the intermuscular septum is reached. At the anterior-distal aspect of the septum, the Brachioradialis muscle (2) has some insertions that should be carefully divided from the humerus bone (1), to avoid injury to the vascular pedicle. A cuff of muscular fibers can be left attached to the septum especially if a bone fragment will be harvested with the flap. B) At the posterior aspect of the flap, the Posterior radial collateral artery is localized proximally (arrow).

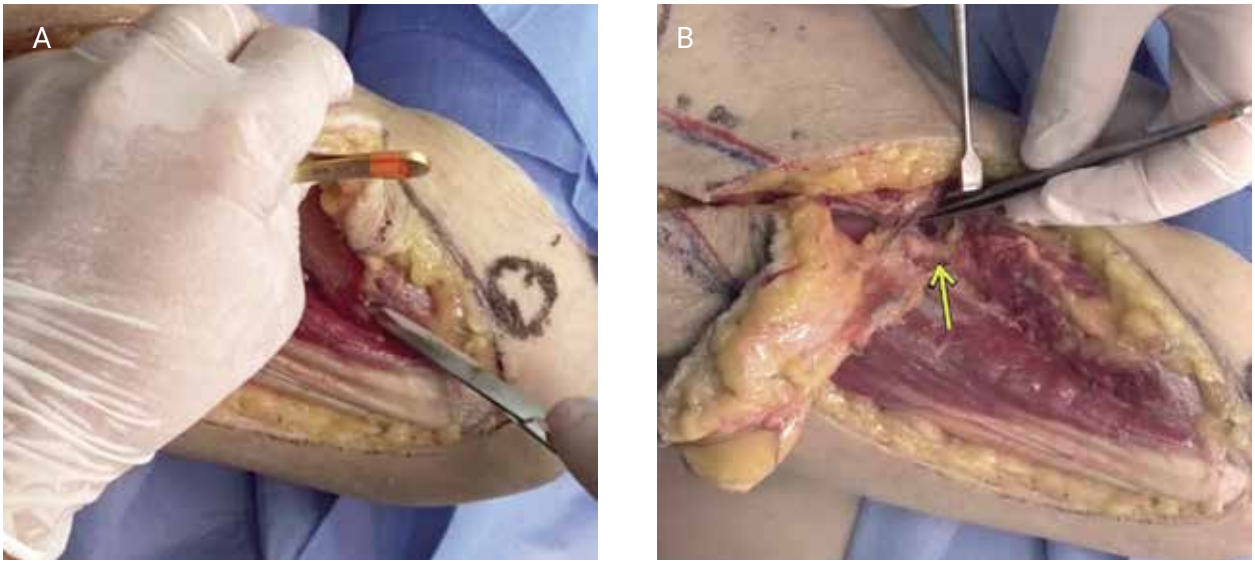


Figure 6.35. A) For proximally based flaps, distal dissection of the septum will expose the PRCA and the Posterior cutaneous nerve of the forearm (PCNF), both are divided and ligated. B) Septum containing the vessels is elevated from distal to proximal and collateral branches from the main pedicle to the muscles are carefully identified, divided and ligated. At this stage the radial nerve can be palpated anterior to the septum, between the brachialis and brachioradialis muscles.

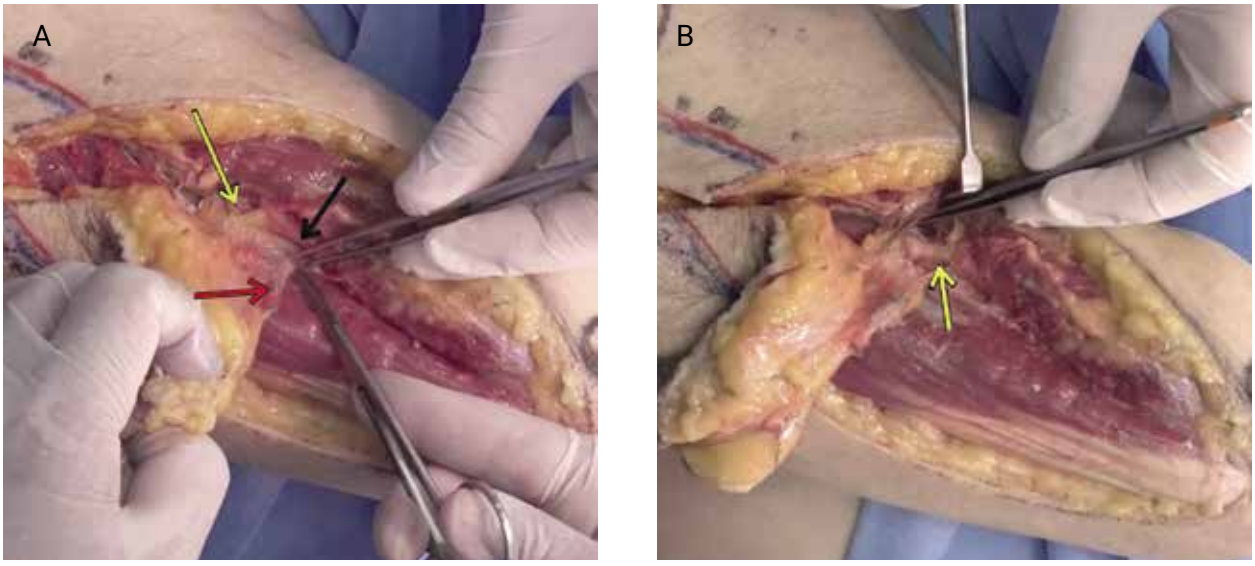


Figure 6.36. A) Intermuscular septum is strongly attached to the humerus bone. To keep a safe plane of dissection and preserve the PCRA and Radial nerve, the flap is elevated strictly at the level of the periostium. B) Proximally, the fascia is gently opened and the radial nerve, covered by the brachialis muscle, exposed (yellow arrow). The anterior radial collateral artery that accompanies the radial nerve does not contribute to the flap vascularization.

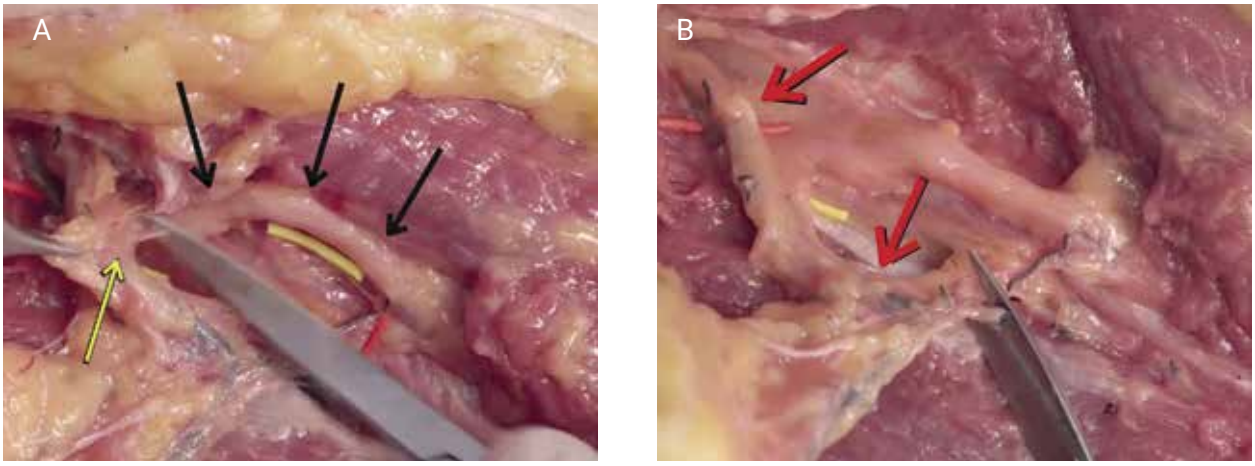


Figure 6.37. A) Dissection is continued proximally and, before the main pedicle is found, the posterior cutaneous nerve (yellow arrow) of the arm is seen branching off from the radial nerve (black arrows). B) Once the Radial nerve has been identified, any collateral vessel still branching off from the PRCA to the muscles is divided to gain length for the pedicle (1). Distal end of the PRCA is seen over the scissors (2). Red arrows indicate the pedicle to the flap. Both the PCRA and the PCN are included.

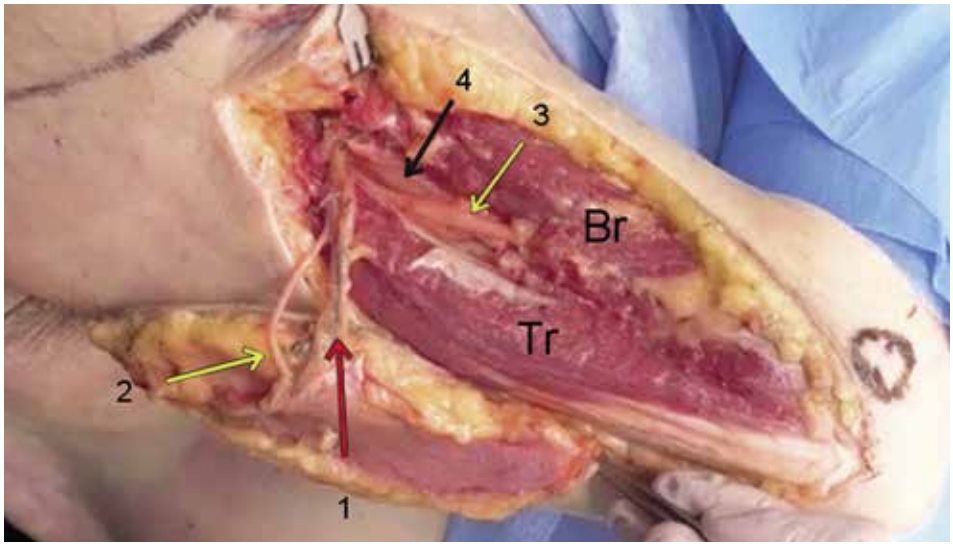


Figure 6.38. Final aspect of the elevated flap: 1: Vascular pedicle. 2: Posterior cutaneous nerve. 3 Radial nerve. 4: Humerus shaft.

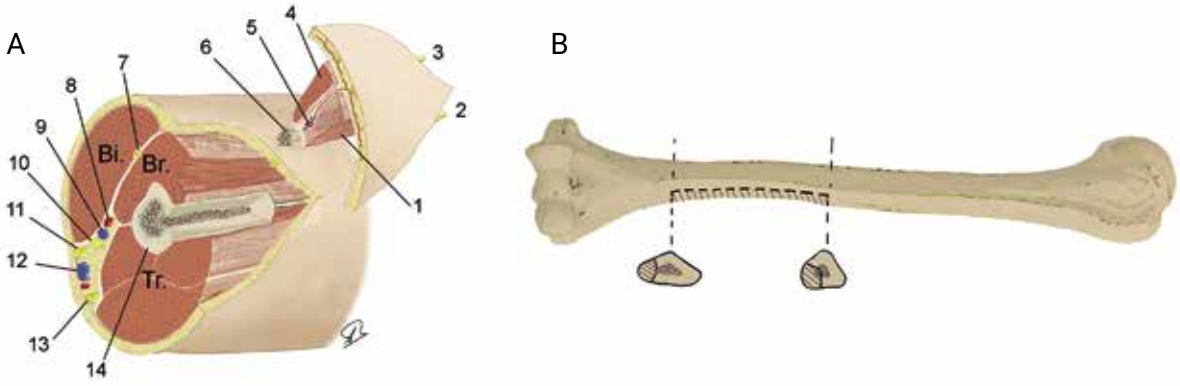
At this stage, the pedicle (and the nerve) can be divided if the pedicle is considered long enough. If more length for the pedicle is desired, dissection should continue cranially between the lateral and medial head of the Triceps muscle, which have to be split, in order to gain access to the vessels. Great care has to be taken to identify and preserve the motor branches to the Triceps muscle.

OSTEOCUTANEOUS FLAP

This flap offers the option to be transferred as an osteocutaneous flap. The PRCA not only gives branches to the skin through the intermuscular septum, it also gives branches to the humerus. According to Haas et al.[33], one or two branches entering the humerus can be found at 2 cm to 7 cm proximal to the lateral epicondyle. The bone segment that is raised with the flap is harvested on that area (fig 6.39). Though a muscular cuff from the Brachioradialis and/or Triceps is not strictly necessary due to these direct vessels from the PRCA, it can be an advisable option[17]. The bone segment can measure from 10-15 cm in length by 1-1.5 cm in width[68]. However, the amount of bone to be harvested is limited, because of the potential risk of stress fracture (Refer to figure 6.39b where the length and the sections of bone that can be safely harvested are shown).

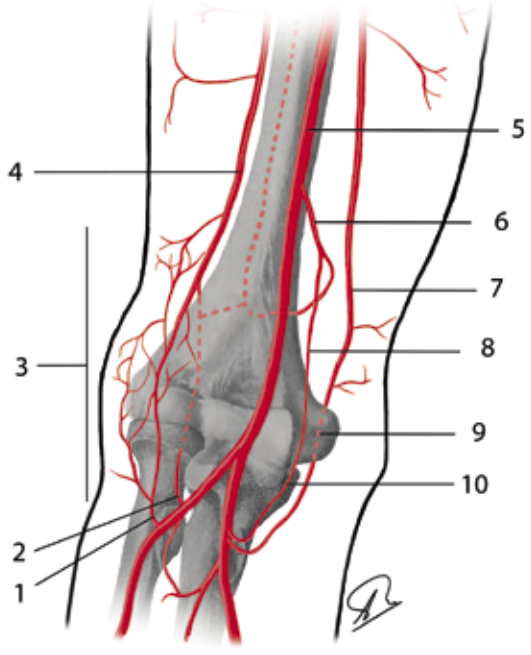
EXTENDED LATERAL ARM FLAP.

During its course down to the elbow, the Posterior radial collateral artery becomes more superficial and, at the epicondylar and olecranon area, its terminal branches anastomose with terminal branches from the interosseous recurrent artery, and principally, the radial recurrent arteries (see fig 6.40). This superficial anastomosing plexus, that supplies the skin of the elbow and lateral forearm, is the basis for the extended lateral arm flap, or the distally based lateral arm flap (see below)[7,75]. The extended version of the flap should then include the radial recurrent artery.



1 Optional muscle cuff from triceps
2 Lower lateral cutaneous n
3 Upper lateral cutaneous n
4 Optional muscle cuff from brachioradialis
5 PRCA, intermuscular septum and perforator vessels
6 Bone fragment from the humerus
7 Radial n
8 Deep brachial artery
9 Deep brachial vein
10 Median n
11 Forearm cutaneous nerve
12 Basilic vein
13 Ulnar n
14 Humerus shaft

Figure 6.39. Osteofasciocutaneous lateral arm flap. A) Section of the left arm with the flap already rasied, showing a fragment from the lateral humeral shaft. B) Left humerus bone showing the area and corresponding sections of the shaft, which are suitable to be harvested with the Lateral arm flap.



1 Radial recurrent a
2 Interosseous recurrent a
3 Anastomosing elbow plexus between the PRCA, the radial recurrent and interosseous recurrent arteries
4 Posterior radial collateral artery
5 Brachial a
6 Inferior ulnar collateral artery
7 Superior ulnar collateral artery
8 Anterior ulnar recurrent artery
9 Posterior ulnar recurrent artery
10 Anterior ulnar recurrent artery

Figure 6.40. Elbow arteries.

The flap can be extended over an axis traced between the lateral epicondyle and styloid process. The skin area can measure up to 12-16 cm distal, to the lateral epicondyle, over the proximal radial region of the forearm[59]. The width will depend, however, on the defect's needs and the possibility of a primary repair of the donor area.

The flap can be raised in continuity, as a single unit: classical lateral arm skin paddle, plus proximal radial forearm skin, or as a distant posterolateral forearm cutaneous flap (reverse distal arm flap will be treated later).

As an extended flap, the lateral arm flap is first harvested, identifying and raising the intermuscular septum, the PRCA and the PCN, stopping dissection over the elbow. The forearm cutaneous extension of the flap is then raised. Though it is not strictly necessary to raise the flap subfascially, elevating the fascia with the flap is highly advisable, as the deep fascial plexus is then better respected and protected. However, this option not only adds up to 12 cm of forearm skin to the classical lateral arm flap, (according to Brandt[7], the flap itself is thin, elastic and sensitive if it is transferred with the PCN.

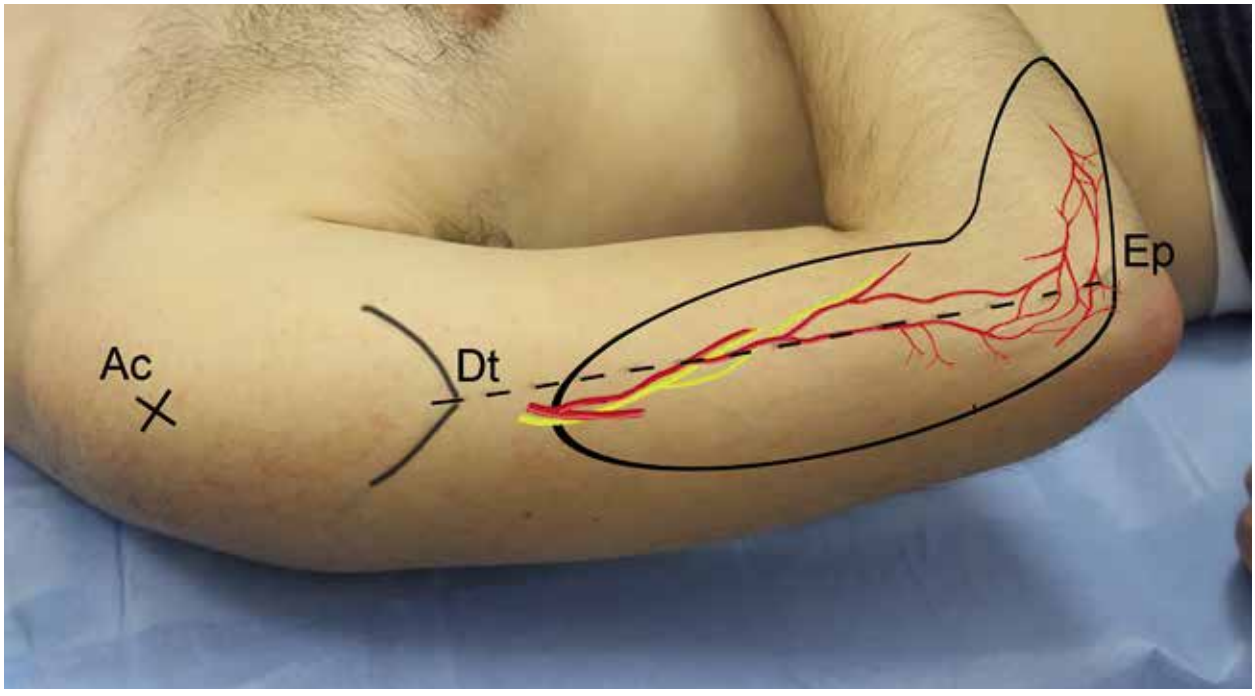


Figure 6.41. Outlining of the extended lateral arm flap.