Pedicled Radial Forearm Flap

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The radial forearm flap is a useful and versatile fasciocutaneous flap designed on the radial artery. It was initially developed as a free flap in 1978 by Yang Goufan and coworkers in China.\(^1\) It was subsequently described as a pedicled flap using either antegrade or retrograde blood flow.\(^2\) In 1979 Foucher and Braun reported mobilizing the radial artery in the snuffbox and passing an island flap underneath the thumb extensors to allow the flap to reach the thumb tip.\(^3\) The flap includes the volar forearm skin, the underlying antebra- chial fascia, and the intermuscular fascia, which contains the radial artery and its cutaneous branches. It can be innervated by the medial and lateral antebrachial cutaneous nerves. With retrograde flaps, neurorrhaphy to the local nerves is required.

### Indications

- A reverse pedicled radial forearm flap can be used for acute and chronic soft-tissue reconstruction of the upper limb.
- There is no specific age range or time limit for this procedure.
- It can be used for coverage of the palm or extensor surface of the carpus, with or without vascularized tendon.
- An antegrade flap can be used for coverage of elbow defects. It provides a durable surface for coverage of amputation stumps near the wrist.

### Contraindications

- Underdevelopment of the radial artery or injury to the superficial and deep palmar arches would preclude the use of this flap, as would the absence of a connection between the radial and ulnar arteries.
- In a cadaver dissection of 650 cadaver arms, only 3.2% had no communication between the radial and ulnar artery, and 3% had an incomplete deep arch. If both of these variations are present, the thumb will be dependent on the radial artery (~1 in 1,100). This can be identified by a preoperative Allen test. Vein graft reconstruction of the radial artery would be necessary in these cases.
- Care should be exercised in acute trauma when hematoma extends to the snuffbox.

### Examination/Imaging

- An Allen test with the aid of Doppler ultrasound is needed to assess the patency of the radial artery.
- Angiography may be necessary if there is any doubt.

### Relevant Anatomy

- The skin of the forearm flexor surface does not have any truly axial artery. An axial pattern flap is effectively created by raising a flap, including the fascial and subcutaneous vessels with their longitudinal orientation and interconnections.
- The entire radial artery from its brachial artery origin to the wrist can be transferred. For most of its course, the radial artery lies under the brachioradialis.
- The pronator teres, flexor pollicis longus, and pronator quadratus lie deep to the artery. The superficial radial nerve (SRN) is lateral to the artery under the brachioradialis.
- After giving off the radial recurrent artery near its origin, the radial artery has no named branches until it reaches the wrist. Here it gives off a superficial palmar branch and a palmar carpal branch.
- One cadaver study demonstrated between 9 and 17 branches from the radial artery to the fascia along the flexor surface of the forearm. The branches supplying the skin are contained in an intermuscular septum between the brachioradialis and the flexor carpi radialis (Fig. 4.1). These branches are arranged into a proximal and distal group, with corresponding zones of perfusion.
The medial and lateral antebrachial cutaneous nerves enter the proximal margin of the flap and supply sensibility to the volar forearm.

The radial artery gives off at least two periosteal branches of 0.2 mm to 0.5 mm in size along the lateral aspect of the radius, immediately distal to the pronator teres insertion. These branches are accompanied by two small venae comitantes and pass along the fascial layer deep to the extensores carpi radialis longus and brevis.

Musculoperiosteal vessels form a constant source of blood supply over the anterior aspect of the distal shaft. They are in turn fed by branches of the radial artery supplying the flexor pollicis longus and pronator quadratus.

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Venous drainage of the radial forearm flap is by means of both the superficial and deep veins. There are three subcutaneous veins, including the cephalic, basilic, and median forearm vein, as well as the paired deep venae comitantes of the radial artery.

A reverse pedicled flap is drained by means of retrograde flow through the venae comitantes. Normally, the venous valves prevent backflow. When a distally based flap is raised, the veins are denervated. The veins are kept filled by blood from the wrist and hand, which leads to an increased venous pressure after ligation of their proximal ends. One author postulated that the combination of these factors allows reverse flow through the venous valves.

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In the distal half of the forearm, there are branches every 1 to 2 cm. As elsewhere, one vascular zone can be extended into another. The distal zone vessels can perfuse a fasciocutaneous flap as far proximal as the elbow. In a reverse pedicled flap, the skin blood supply is dependent on retrograde flow from the ulnar artery through the deep palmar arch.

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**Surgical Technique**

- The patient is positioned supine with the arm abducted on an arm board. The surgeon sits facing the volar forearm when harvesting the flap but may switch to the other side when insetting the flap. The procedure is done under brachial block or general anesthesia using loupe magnification, but the operating microscope may be needed for any venous anastomoses or neurorrhaphy. A tourniquet is used for the initial dissection, and the limb is only partially exsanguinated with an Ace wrap rather than an Esmarch bandage to facilitate identification of the vessels.
- The courses of the radial artery and the superficial veins are marked. The flap axis is slightly medial to the course of the radial artery.
- Using a pattern from the recipient site, outline the size of the defect on the proximal forearm. If the flap is outlined over the proximal ulnar forearm, it will be thinner and less hair-bearing (Fig. 4.2a–c).
- A thin skin island can be left over the course of the radial artery to prevent the need for skin grafting the pedicle later on and to avoid an overlying skin bridge (Fig. 4.3).
- Incise the flap down to the deep fascia. Harvest veins along the proximal medial border of the flap. This allows an easier anastomosis with local veins once the flap has been rotated 180 degrees.
- Identify the medial or lateral antebrachial cutaneous nerve, and then make a proximal extensile incision for a longer nerve pedicle (Fig. 4.4a–c). The SRN should be protected to preserve sensation to the radial aspect of the hand.
- Develop a plane deep to the radial artery at the wrist and find the intermuscular septum between the flexor carpi radialis (FCR) and the brachioradialis. Incise the deep fascia over the FCR muscle belly, well medial to the intermuscular septum.

![Diagram](image1)

**Fig. 4.2a–c** (a) The flap axis is shown by a straight line down the midline of the forearm that is slightly medial to the radial artery (RA). The flap may be outlined anywhere along the flap axis. (b) The flap (in blue) is raised subfascially to the lateral border of the flexor carpi radialis (FCR). The deep dissection includes the intermuscular septum. PL, palmaris longus; FDS, flexor digitorum sublimus; FCU, flexor carpi ulnaris. (c) Cross-section through the forearm distal to the pronator teres showing the position of the radial artery (RA) and plane of dissection for elevation of a fasciocutaneous flap. FCR, flexor carpi radialis; FPL, flexor pollicus longus; FDS, flexor digitorum sublimus; FDP, flexor digitorum profundus; FCU, flexor carpi ulnaris; BR, brachioradialis; UA, ulnar artery.
Fig. 4.3  Reverse pedicle skin flap with a skin bridge (SB) over the radial artery pedicle.

Fig. 4.4a–c  (a) Diagram of the flap, which includes the radial artery (RA) and venae comitantes, the cephalic vein (CV), and potentially either the medial (MABCN) or lateral (LABCN) antebrachial cutaneous nerve.  (b) Elevation of a reverse pedicle flap.  Note the proximal extensile incision (arrow) for harvest of a nerve graft.  (c) Pedicled flap with incorporation of the lateral antebrachial cutaneous nerve (arrow) and vascularized palmaris longus tendon (*).
• Dissect the interval between the deep fascia and the muscle. Suture the deep fascia to the skin flap to minimize shear on the septocutaneous perforators. Continue the dissection deep to the radial artery on both sides of the septum. The fascia superficial to the radial artery is left undisturbed because it contains the septocutaneous perforators that supply the skin flap (Fig. 4.5a–e).

• After the flap dissection is complete, apply a microvascular clamp to the proximal radial artery prior to releasing the tourniquet. If there is adequate perfusion to the flap and the thumb with the tourniquet deflated, then the artery is divided.

• Raise the flap, ligating all the perforators deep to the artery. Transpose the flap to the dorsum of the hand. If desired, perform a venous anastomosis prior to insetting the flap (Fig. 4.6).

Fig. 4.5a–e (a) Gunshot wound with bone and soft-tissue loss. (b) Iliac crest bone graft reconstruction of metacarpal. (c) Plate fixation and extensor indicis proprius tendon graft. (d) 3 × 3 cm reverse pedicled radial forearm flap outlined on proximal forearm. (e) Immediate postoperative result.
Vascularized Bone Dissection

- The vascularized bone graft does not carry an intact endosteal blood supply, but instead survives on the periosteal branches.
- The lateral half of the radius from the insertion of the pronator teres to the metaphyseal flare of the distal radius can be harvested. Up to 10 cm of slightly curved, mostly cortical bone, comprising half the circumference of a circle, is obtained (Fig. 4.7a, b).
- Preserve the perforators deep in the radial artery along the length of the desired bone graft. Dissect medial to the intermuscular fascia over the radius.
- Divide the pronator teres, sublimus muscle, and flexor pollicis longus muscle directly on top of the midline of the bone. This preserves the musculoperiosteal branches to the bone graft.
- Predrill the osteotomy site prior to performing the osteotomy. Bevel the proximal and distal corners to decrease stress risers and to diminish the risk of postoperative fracture.

Pearls

- Distally based radial forearm flaps designed on the proximal forearm can easily reach the dorsal and palmar surfaces of the hand. They can include vascularized tendon and bone.
- Pedicle lengths up to 15 cm are possible. If the flap is less than 6 cm in width, the donor site can be closed primarily. A thin skin island can be left over the course of the radial artery to prevent the need for skin grafting the pedicle later on and to avoid an overlying skin bridge.
- The flap arc of rotation can be increased by freeing the radial artery in the snuffbox and passing the flap underneath the thumb extensors. This allows the flap to reach as far as the thumb tip.
- Over the distal volar forearm, the flap is thin with little fat, but it leaves a poor bed for skin grafting, consisting of tendons covered only by paratenon.
- A proximal flap is hair-bearing and thicker since it has more subcutaneous fat. The donor site contains muscle bellies, which is more favorable for skin grafting.
- Avoidance of the distal forearm as a donor site and covering the tendons with adjacent muscle fibers from portions of the brachioradialis, flexor digitorum, superficialis, and flexor carpi ulnaris provide a better skin graft bed.
- Unmeshed skin grafts can be used to maximize the bridging phenomenon. Preoperative tissue expansion can also be used.
- The forearm flap permits postoperative elevation and early mobilization of the injured limb.
- Proximally based flaps can be used to resurface defects well above the elbow joint. These flaps are directly innervated by including the medial or lateral cutaneous nerve of the forearm.
Fascial Fat Flap Dissection

- A fascial fat flap is raised in a similar manner to the fasciocutaneous flap. The plane of dissection can be subfascial and proceed between the deep fascia and the skin, which divides all the cutaneous branches, or it can be suprafascial, leaving the deep fascia intact.
- A recent anatomical study found no difference in perfusion of the radial forearm harvested with or without the deep fascia. The potential advantages of preservation of the deep fascia include prevention of tendon exposure or the formation of adhesions with the overlying graft and a superior bed for skin grafting. The suprafascial dissection plane also facilitates visualization and therefore protection of the superficial radial and lateral antebrachial cutaneous nerves.
- The reverse radial fascial fat flap survives on retrograde blood flow through perforating vessels coming off the radial artery. These perforators are found within 1.5 to 7 cm of the radial styloid and run directly upward from the radial artery into the fascia.
- The most proximal perforators are sacrificed for retrograde orientation of this flap. The fat and deep fascia are developed as a long, distally based rectangular flap.
- The interval between the fat and fascia is not violated. The lateral antebrachial cutaneous nerve and SRN are preserved.
- After elevation, the flap is turned distally 180 degrees and simultaneously twisted 90 degrees to place the vascularized fat layer directly over the median nerve (Fig. 4.8a, b).
- A fascia-alone flap can be elevated. Clinical experience has shown this variant is still reliable and eliminates some of the bulkiness of the flap, even though the actual subfascial plexus is very poorly developed.
- The donor site is closed primarily.

Fig. 4.7a, b  Vascularized bone graft. (a) Cross-section through the forearm distal to the pronator teres showing the position of the radial artery (RA) and plane of dissection for elevation of a composite flap (blue) with vascularized radius bone graft (red). FCR, flexor carpi radialis; FPL, flexor pollicis longus; PL, palmaris longus; FDS, flexor digitorum sublimus; FDP, flexor digitorum profundus; FCU, flexor carpi ulnaris; BR, brachioradialis; UA, ulnar artery. (b) Diagram of the flap, which includes the radial artery (RA) and venae comitantes with a section of vascularized distal radius attached by the intermuscular septum.
Postoperative Management

- Postoperatively the patient is admitted for monitoring and the limb is elevated on 1 pillow.
- Flap edema with limb dependency must be balanced against the decreased pulse pressure when pumping “uphill.”
- Anticoagulation is not routinely used for elective flaps unless there is a compromise of flap circulation. In the face of acute trauma or massive crush injury with a hypercoagulable state, a single 10,000 unit dose of heparin may be administered prior to tourniquet elevation. Postoperative anticoagulation with dextran or heparin is up to the surgeon’s discretion. A daily baby aspirin may be considered if a venous anastomosis is performed.

Pitfalls/Complications

- Postoperative complications include flap edema, unstable skin graft over tendons, hand swelling, and SRN injury.
- Flap edema is common due to associated forearm injury or impaired venous drainage. Additional venous anastomoses will help minimize this.
- Skin graft failure is most likely to occur over tendons, especially the FCR. Even when they have successfully taken on tendons, skin grafts may suffer recurrent breakdown.
- The donor site defect is quite noticeable. The flap is hair-bearing and often bulky.
- A radial shaft fracture can occur following harvest of vascularized bone; hence, above-elbow casting or splinting for up to 8 weeks is recommended.
- Although digital temperature comparisons show an average 2.5% decrease following the use of the radial forearm flap, cold intolerance is often transient.

Outcomes

- The versatility of this flap is highlighted by a series reported by Jones et al on their experience with 67 radial forearm flaps. There were 43 reverse flow, 14 antegrade flow, and 10 free radial forearm flaps, including seven fascial flaps and one osteocutaneous flap. Their indications included soft-tissue coverage of the elbow, wrist and hand coverage, radioulnar synostosis before toe-to-thumb transfers, tumor reconstruction, and nerve wrapping. The soft-tissue defect healed in 95%. There was one flap dehiscence, partial loss of two reverse flow flaps, and complete loss of one free radial forearm flap. No patients complained of cold intolerance of the hand or dysesthesias.

- In a similar study, Yajima and coauthors described the outcomes in 37 patients who were treated with a distally based island radial forearm flap. This included coverage of the dorsum of the hand (n = 17), the thumb (n = 11), the fingers (n = 5), the first web (n = 3), and the palm (n = 1). There were 15 innervated flaps (mean moving two-point discrimination [2PD] of 13 mm), six osteocutaneous flaps, and eight tendocutaneous flaps (two requiring tenolysis). All of the flaps survived. There were five donor-site complications and three patients with cold intolerance. There were no radial fractures.
References