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Radial Forearm Free Flap

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Abstract

Background: **Free flap procedure has become a gold standard in reconstructive plastic surgery especially for a difficult wound, a complex tissue defect, or a three-dimensional defect in all areas of the body. At present, there are many donor sites of free flaps and among them the radial forearm free flap is the most popular free flap performed at Ramathibodi Hosiptal.**

Objective: **To retrospectively study the outcomes of 49 consecutive radial forearm free flaps performed at Ramathibodi Hospital during the 10-year-experience from September 1986 to September 1996.**

Materials & Methods: **There were 177 different free flaps, and radial forearm free flap was the most common (49/177 = 33.3%) and reliable flap used for reconstruction of head and neck region including esophagus, lower and upper extremity defects. All important steps of flap dissections and microvascular anastomoses were performed by the authors. There were three osteofasciocutaneous radial forearm free flaps in which a segment of radius was included as a composite free flap for reconstruction of one metatarsal bone and two hemimandibles. The rest were radial forearm fasciocutaneous free flaps. All secondary defects of the forearms but one were closed by split-thickness skin grafts. No interposition vein grafts were used for microvascular anastomoses. No monitoring devices were used post-operatively to observe the viability of the flaps. Only close observation of clinical signs to detect early vascular compromise was made by surgical residents and nurses.**

Results: **Three flaps developed early venous congestion. They were relieved and salvaged by leeches and the other three flaps with doubtful vascular compromise were immediately explored when thrombectomy, employing a thrombolytic agent, and redoing microvascular anastomoses were carried out. There were neither systemic complications nor hospital mortality. All radial forearm free flap reconstructions achieved good and satisfactory results. As far as the hand function and esthetic appearance of the grafted skin at the forearm were concerned, the morbidity of the donor site was not significant. No patients developed cold intolerance of the donor hands. However, a decision should be carefully weighed before harvesting this flap in a young lady.**

Conclusion: **Based on our experience, we conclude that the radial forearm free flap is safe, reliable, versatile and ideal for reconstruction of the head and neck region where the subcutaneous fat tissue is less as well as in the lower extremity.**

The radial forearm free flap was initially developed in 1978 by Chinese postgraduate doctors (Dr Yan Guofan, Dr Chen Baoqui and Dr Gao Yuzhi), at Shenyang Military Hospital. They used the radial forearm flap as a free flap supplied by the radial artery for correction of severe neck burn scar contractures reported in the National Medical Journal of China in 1981.[1] One year later in 1982, their teacher, Dr Ruyao Song, et al reported this flap in English literature and called it "the forearm flap".[2] In 1984, the Society of Plastic and Reconstructive Surgeons of Thailand invited Dr Song as a guest speaker to talk about "Advances of Microsurgery in China" and "The Forearm Flap" during the Second Asean Congress of Plastic Surgery held in Bangkok, Thailand.[3] In 1981, Dr Shaw[4] referred to a case of nasal reconstruction in one stage using the forearm flap without bony support performed by RY Xia of the Third Affiliated Hospital of Beijing Medical College.

In November 1980, Dr Wolfgang Mühlbauer from West Germany visited the People's Republic of China on a lecture tour and saw the work at Ba-Da-Chung Hospital for Plastic and Reconstructive Surgery near Peking. In March 1981, he then presented his studies in the cadavers and successful clinical experiences of the forearm flaps at the Eight Alpine Workshop on Plastic Surgery, at Cortina d'Ampezzo, Italy and later reported this paper in 1982.[5] Subsequently, his colleague, Dr Biermer[6], reported the extended technique to include a piece of radius as an osteo-cutaneous forearm island flap for reconstruction of the thumb. Drs Reid and Moss[7] nicknamed this flap "Chinese Forearm Flap" to dedicate the honor to Chinese doctors. They also included tendons with the flap for reconstruction of a dorsal hand injury. Soon after their paper was published, this flap was shortly called in the UK and Europe "The Chinese Flap". Dr David Soutar and his colleagues called this flap "The Radial Forearm Flap" since this flap is supplied by a radial artery and they reported the success of using this free flap for intra-oral reconstruction and for the management of soft tissue injuries of the hand as a reversed island flap.[8,9]

Anatomically forearm skin is supplied by both radial and ulnar arteries. Instead of using a radial artery, Dr Lovie, et al utilized ulnar artery included with this flap and named it "the ulnar artery forearm free flap".[10] But this flap had not been generally accepted because ulnar artery was the dominant artery of the hand and should be preserved. This was supported by the studies of Drs Lamberty and Cormack.[11]

Our early experiences and reports[12-15] had made the radial forearm free flap (RFFF) popularized among Thai doctors and many Institutes have started using this flap for reconstructive microsurgical procedures in Thailand.

Materials and Methods

Patients

From the report of 177 free flaps performed at Ramathibodi Hospital, during September 1986-September 1996, the overall success rate was 96.06 per cent and the most common and popular free flap was the RFFF (49/177 = 33. 3%).[14] Retrospective studies of 49 RFFFs revealed that they were performed in 49 patients. They were 37 males, 12 females; ages ranged from 16-72 years (average 52.4 years), and 25-71 years (average 54.6 years) respectively.

The RFFFs were employed for reconstruction of 23 intra-oral defects following tumor ablation, 8 burn scar contractures at neck, 3 esophageal defects, 12 lower extremity defects, 2 prefabricated ear reconstructions and 1 contralateral upper extremity defect (Table 1).

Anatomical Consideration (Figure 1)

The radial forearm flap (RFF) is a type C

Table 1 Various defects of the body which were reconstructed by radial forearm free flaps

Defect	No.
● Head and Neck	
- following wide resection of intra-oral cancer	23
- burn scar contracture at neck	8
- following wide resection of esophageal cancer	2
- prefabricated ear reconstruction	2
- following resection of esophagus from acid burn	1
● Lower extremity	
- trauma	8
- venous ulcer	4
● Upper extremity	
- electrical injury	1
Total	**49**

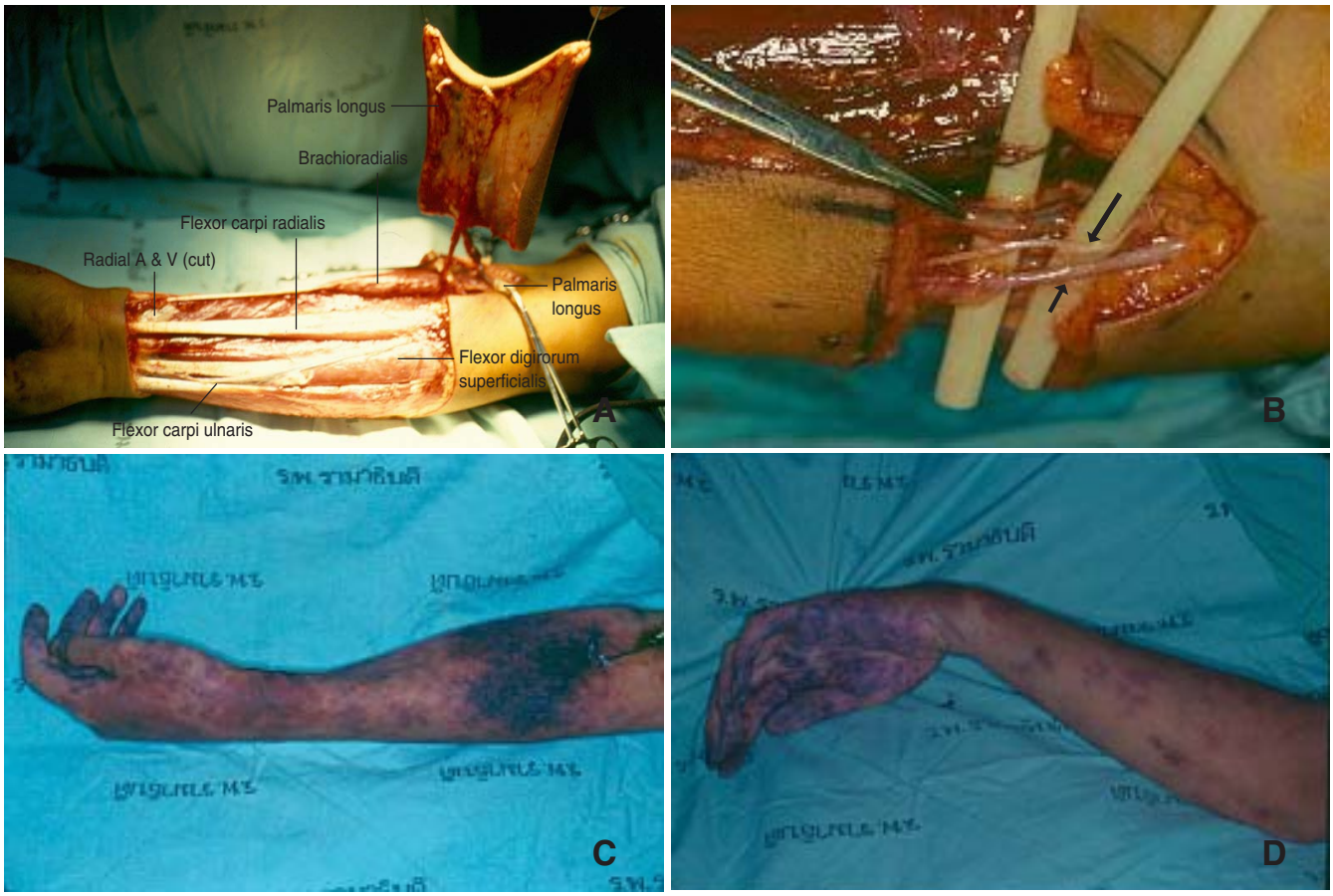


Fig. 1 Photographs in cadaver study.
A. A proximally based radial forearm island flap was developed; when the vascular pedicle was divided, it became a radial forearm free flap. The secondary defect was well-vascularized for skin grafting procedure.
B. Demonstrating the neurovascular pedicle. The artery forceps was pointing at the radial artery with its venae comitantes. A long arrow was pointing at the lateral cutaneous nerve of the forearm. A short arrow was pointing at the cephalic vein.
C. and D. Following injection of Indian ink into the radial artery of a fresh cadaver, it showed that the ink distributed through the whole skin of the forearm and hand.

fasciocutaneous flap[11] based on septocutaneous perforators from the radial artery for the blood supply. The radial artery courses in the lateral intermuscular septum between flexor carpi radialis (FCR) and brachioradialis (BR) muscles in the distal two-thirds of the forearm. Many cutaneous branches arise from the perforators of the radial artery, supplying the skin of the lower forearm jointly with cutaneous branches of the ulnar and interosseous arteries. These perforators are plentiful in the distal third of the forearm; but proximally, where tendons give way to muscle bellies, they become rather sparse. Nevertheless, it is probably safe to raise a septum-based skin flap anywhere along the course of the radial artery. In this way, two skin paddles may be raised, one proximal and one distal, to facilitate reconstruction of the through-and-through defect.

Venous drainage is provided by two venae comitantes (deep veins) which accompany the artery and additional subcutaneous forearm veins (superficial veins) which drain into the cephalic, basilic and median cubital veins. The two venous systems communicate via a branch which drains into the median cubital vein. The superficial veins of 2-3 mm in diameter are often preferred because of their greater diameter and their independence from the arterial pedicle. Care should be taken, however, to ensure that the superficial veins have not been previously canalized nor undergone partial or complete thromboses.

The superficial radial nerve runs along the radial border of the forearm under the cover of the BR toward the dorsum of the wrist, where it pierces the

deep fascia and divides into lateral and medial branches. The vascular basis provides a donor for a vascularized radial nerve graft. The forearm skin is innervated by the lateral (C5, C6) and medial (C8, T1) cutaneous nerves of the forearm and these nerves, lying in the plane superficial to the deep fascia, are readily elevated with the flap to form a sensate flap. A segment of radius carried by this flap, called osteofasciocutaneous flap, is approximately one third of the cross sectional area of distal anterolateral radius. It has a constant source of blood supply from branches of the radial artery passing directly to the periosteum in the intermuscular septum and from musculoperiosteal vessels that pass the flexor pollicis longus (FPL) muscle.[11]

The fresh cadaveric injection studies show that one radial artery can supply the whole skin of the forearm and hand (Figure 1 C,D), so any part of the forearm skin can be used, nevertheless in practice, the presence of hair, which is not suitable for intra-oral lining, may dictate the site of the flap. However, this problem has not been of concern in most Thai patients as their forearms are quite hairless.

Surgical Preparation and Technique

Pre-operatively, the Allen's test was performed to ascertain that the whole hand could be nourished by one ulnar artery, and thus the radial artery would be expendable. Intravenous puncture for drawing blood or infusion therapy of the donor forearm was prohibited to prevent intima trauma or venous thrombosis. The course of radial artery and superficial vein(s) were outlined on the donor forearm. The required size and shape of the flap, measured from the pattern of the defect, were mapped out on the flexor or radiodorsal surface of the forearm such that all proposed flap amply overlay these vessels with proper orientation to simplify any microvascular anastomoses at the recipient site. Distally design flap had an advantage of being thinner than proximal flap, particularly noticeable in female patients. Furthermore, it was the choice where radial bone would be included in the flap or required a long vascular pedicle. The disadvantage of distal flap had been the difficulty of retaining a donor defect with intact paratenon suitable for skin grafting procedure.

The upper arm tourniquet was properly inflated following incomplete exsanguination. Thus, capillary bleeding of the remaining blood seen during dissection could be completely and atraumaticly coagulated by a bipolar diathermy to prevent post-operative hematoma. The flap elevation was started on the ulnar side where the thicken deep forearm fascia was more easily identifiable. The plane of dissection was kept just deep to the fascia and a fasciocutaneous flap carefully developed to preserve the lateral intermuscular septum and its perforators from the radial vessels, and also to isolate and preserve the superficial veins as required. The cephalic vein and the superficial nerve were dissected into the deltoid and upper arm respectively to obtain greater length. Elevation of the flap subfascially exposed muscle proximally and tendons with paratenon intact distally for skin graft. The palmaris longus (PL) tendon which lay within a condensation of the deep fascia was freed or included as required; if it was freed, taking care to preserve its paratenon. Care was taken to preserve the superficial branch of the radial nerve by dissection from the undersurface of the flap. This nerve was not used for innervation purposes and virtually not never necessary to sacrifice it. Painful neuroma is a common problem once it is injured and not immediately repaired.

To harvest an osteofasciocutaneous flap, the FPL muscle was identified and longitudinally cut at its insertion on the radius. An anterolateral segment of distal radius of about 8-10 cm in length extending from the insertion of pronator teres to the insertion of BR could be raised in an adult but care should be taken to remove less than half the circumference of the radius to avoid weakening the bone and risking subsequent fracture. It was more convenient to cut the radius from the radial (lateral) aspect. Distally, the radial artery and its venae comitantes were identified, separately ligated and divided. The flap was now completely developed as a proximally based island flap. The tourniquet was released, and the flap and its vascular pedicle were assessed for circulation. Meticulous hemostasis was accomplished by the usual means. The flap margins were observed for good capillary bleeding and the venous outflow. Perfusion of the hand by the ulnar artery was also assessed at this stage. With proper pre-operative assessment, there should be no surprises. Nevertheless, the surgeon should be prepared to graft the radial artery if faced with obvious arterial insufficiency; in practice, this had been extremely rare.

In a proximal flap, a long vascular pedicle was raised distally and used for microvascular anastomoses,

thus providing a retrograde arterial inflow and venous outflow. So, either end of the radial artery might be anastomosed in an antegrade or retrograde manner. As a reversed flow, the radial forearm island flap was used for hand reconstruction. A flow-through flap to maintain or reconstruct the arterial defect as well as the skin was established when both ends of the radial artery had been anastomosed to both ends of the recipient artery. Routinely, the radial artery was anastomosed first to reveal normal venous outflow; and whenever possible, more than one venous anastomosis was carried out. Interposition vein graft was rarely indicated if a proper flap design to match the recipient defect had been made.

Post-operative Care

The hemodynamic status was kept stable at all time, intra-operatively and post-operatively, to maintain adequate tissue perfusion. Post-operatively, viability of the RFFF was constantly monitored every 1-2 hours only by clinical signs i.e. skin color and turgor, capillary refill, and needle puncture under aseptic technique. No monitoring devices were used for assessment of post-operative blood flow. For reconstruction of the esophagus, flexible esphagoscopy was used for detection of the skin flap color and the anastomotic sites. This technique was indeed not practical but it was necessary in this situation.

Post-operative medications included intravenous administration of dextran-40® for 5 days at 20 ml/hr, aspirin 150 mg (gr. V) orally or rectally per day for 14 days, and dipyridamole (persantin®) 75 mg orally per day for 14 days. Heparin was not prescribed as in replantation surgery. In recent years, with confidence in free flap dissections and techniques of the microvascular anastomoses, we post-operatively administered no anticoagulants in selected cases and those free flaps survived. At present, it is not yet for us to conclude whether anticoagulants are necessary or not to help prevent flap loss. To date, no proven pharmacologic intervention can prevent routine flap failure.[16]

Free flap failure was defined as a complete loss of the flap or partial loss of the flap where enough of the flap was lost to prevent it from providing the desired functional or esthetic result. In other words, a flap loss was one that failed to meet the original reconstructive goal.

Results

Having long vascular pedicle, all microvascular anastomoses were satisfactorily performed without vein graft interposition. The success rate of 49 RFFFs during 1986-1996 was 100 per cent. However, 6 RFFFs had developed vascular occlusions which were detected early within 24 hours. Three grafts were salvaged following decongestion with leeches.[17] Early surgical exploration for vascular thromboses and revision or thrombectomy of the microvascular anastomosis sites before redoing microvascular anastomoses were carried out in another three when vascular compromise was questionable. Also, intra-aterial injection of 100,000 i.u. of streptokinase at the recipient artery for thrombolysis[18] was successfully used in two RFFFs. All secondary defects of the forearms were closed by split-thickness skin grafts except in one which was closed by a V-Y rotation advancement flap based on perforating branches from the ulnar artery. All skin grafts took well and did not need either additional skin grafting procedure or scar revision. There were three radial forearm osteofasciocutaneous free flaps in which a segment of radius was included as a composite free flap for reconstruction of one metatarsal bone and two hemimandibles. Two of donor radial bones healed well except one which broke on the eight post-operative day but healed after proper reduction and immobilization with a forearm slab. Bony union with normal hand function occurred within eight weeks. Neither fascial nor sensate free flaps were used for reconstruction. No vascular reconstitution was done to bridge the radial arterial defect. There was no immediate or long-term cold intolerance of the donor hands and without functional morbidity of the donor hands in term of grip strength, pinching, and sensation. The noticeable esthetic appearance of grafted skin at the forearm were acceptable by all patients including a 25-year-old lady. Normally, each author operated on his own patients. The operating time varied from 5 1/2 hours to 11 hours (average 8 1/2 hours). It was noteworthy that a two-team approach (AK, VV) in some cases, one preparing the recipient site and the other one dissecting the free flap donor site, had shortened the operating time. Post-operative hospital stay ranged from 15 days to 31 days (average 18.2 days). There were neither systemic complications, nor hospital mortality.

Illustrated Case Reports

Case 1 (Figure 2)

A 31-year-old man sustained severe crush injury to the right foot from a motorcycle accident. Seven weeks after the injury, he was refered to us for surgical reconstruction. On examination, there was an avulsion defect measured about 6×10 cm with chronic osteomyelitis of the first, second, and third metatarsal bones. Following radical debridement, a radial forearm osteofasciocutaneous free flap, harvested from left nondominant hand, was used for a salvage procedure while a segment of radius was used for reconstruction of the first metatarsal bone. This case was the first radial forearm free flap which was performed on Monday 29 of September 1986. The post-operative course was uneventful and the restoration of the form and function of the foot was achieved by additional iliac bone graft procedure for reconstruction of the second and third metatarsal bones.

Case 2 (Figure 3)

A 68-year-old lady with the history of long standing betel nut chewing had an ulcerating squamous cell carcinoma measured 4×4.5 cm in diameter at the left side of floor of mouth invading the lower gum and mandible (T4, N1, M0). She was physically fit for long operating time procedure under general anesthesia. Following a composite resection of the tumor and left hemiman-dibulectomy, an immediate reconstruction was carried out using a radial forearm osteofasciocutaneous free flap. The post-operative result was uneventful with satisfactory reconstruction.

She has come to the plastic surgery clinic for regular follow-ups without the evidence of local recurrence or distant metastasis of the tumor for more than 11 years. She has been living with a good quality of life after the operation and the right hand function is normal with no clinical evidence of cold intolerance.

Fig. 2 Photographs of Case 1, a 31-year-old man sustained a severe crush injury to right foot from a motorcycle accident

A. Seven weeks after the injury, he was referred to us for surgical reconstruction. On examination, there was an avulsion defect measured about 6x10 cm with chronic osteomyelitis of the first, second and third metatarsal bones.
B. Following radical debridement of all dead tissues, radial forearm osteofasciocutaneous free flap was used for a salvage procedure of the right foot. The arrows showed a segment of radius from the forearm used for reconstruction of the first metatarsal bone.
C. One week after the operation, simple and modified external fixator was used for bony rigid immobilization.
D. Six months after the operation, the function of the right foot was restored and the esthetic appearance was acceptable.

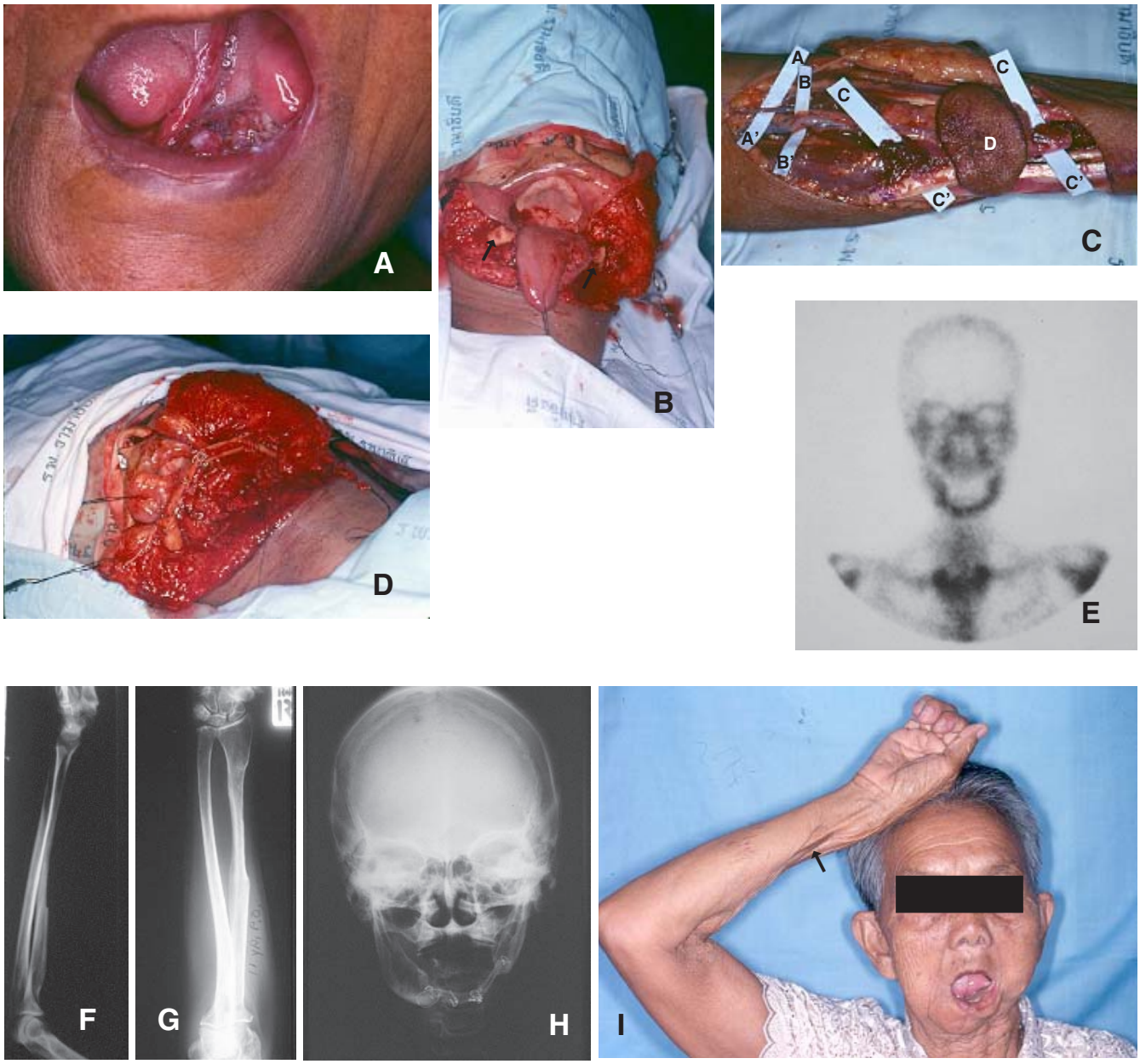


Fig. 3 Photographs of Case 2.

A. A 68-year-old lady had an ulcerating squamous cell carcinoma measured 4×4.5 cm in diameter at left floor of the mouth invading the lower gum and mandible (T4, N1, M0).
B. Following a composite resection, the arrows demonstrated both ends of the mandible after hemimandibulectomy had been performed.
C. A radial forearm osteofasciocutaneous free flap was harvested for reconstruction of the intra-oral lining and the mandible. AA' was basilic vein, BB' was radial artery and its venae comitantes. CC' was a segment of the radius which, having segmental blood supply by the radial artery, could be osteotomized once or twice for accurate contouring in the symphysial and parasymphysial regions. D was a skin paddle.
D. The flap was transferred to cover the defects. The skin paddle was used for intra-oral lining and a segment of the radius, after being fractured and immobilized with interosseous wirings, was used for mandibular reconstruction.
E. Bone scan at the 8th day after the operation revealed good uptake of the radius.
F. X-ray picture of the radius at one week after the operation.
G. X-ray picture of the radius at eleven years after the operation.
H. X-ray picture of the mandible at eleven years after the operation. There was no resorption of the radius and the contour of the mandible was restored.
I. The patient at 79 years old (eleven years after the operation) has been living with a good quality of life and with normal hand function. The arrow showed a donor site of the radial forearm free flap.

Case 3 (Figure 4)

A 24-year-old man suffered from burn scar contracture at neck and lower lip causing leakage of the saliva and food during meals. He could not completely close his eyes when the neck was fully extended. The clinical examination was otherwise normal. Following complete release of the burn scar contracture, a large radial forearm fasciocutaneous free flap measuring 18×24 cm was used for skin coverage. The RFFF having thin subcutaneous fat was ideal for the neck region reconstruction as well as for intra-oral lining. It was well demonstrated in this patient after the operation that the cervicomental angle had been maintained and all facial deformities mentioned above had been corrected.

Case 4 (Figure 5)

A 52-year-old man underwent long segmental resection of the esophageal carcinoma. We were consulted to perform immediate reconstruction of the esophagus. The esophageal defect between the hypopharynx and the esophageal stump was 12 cm in length. It was reconstructed by tubing of the forearm skin from a radial forearm fasciocutaneous free flap. Post-operative evaluation of the flap viability was not possible because we did not use any monitoring devices, although in need in such a case. Furthermore, exteriorising a part of RFFF was not possible. An esophagoscopy was then carefully performed to observe the skin flap color and the anastomosis sites. Fortunately, with the confidence in microvascular anastomoses of one artery and two veins, the post-operative result was uneventful. All wounds healed with no complications and the barium swallow revealed patency of the reconstructed esophagus without leakage.

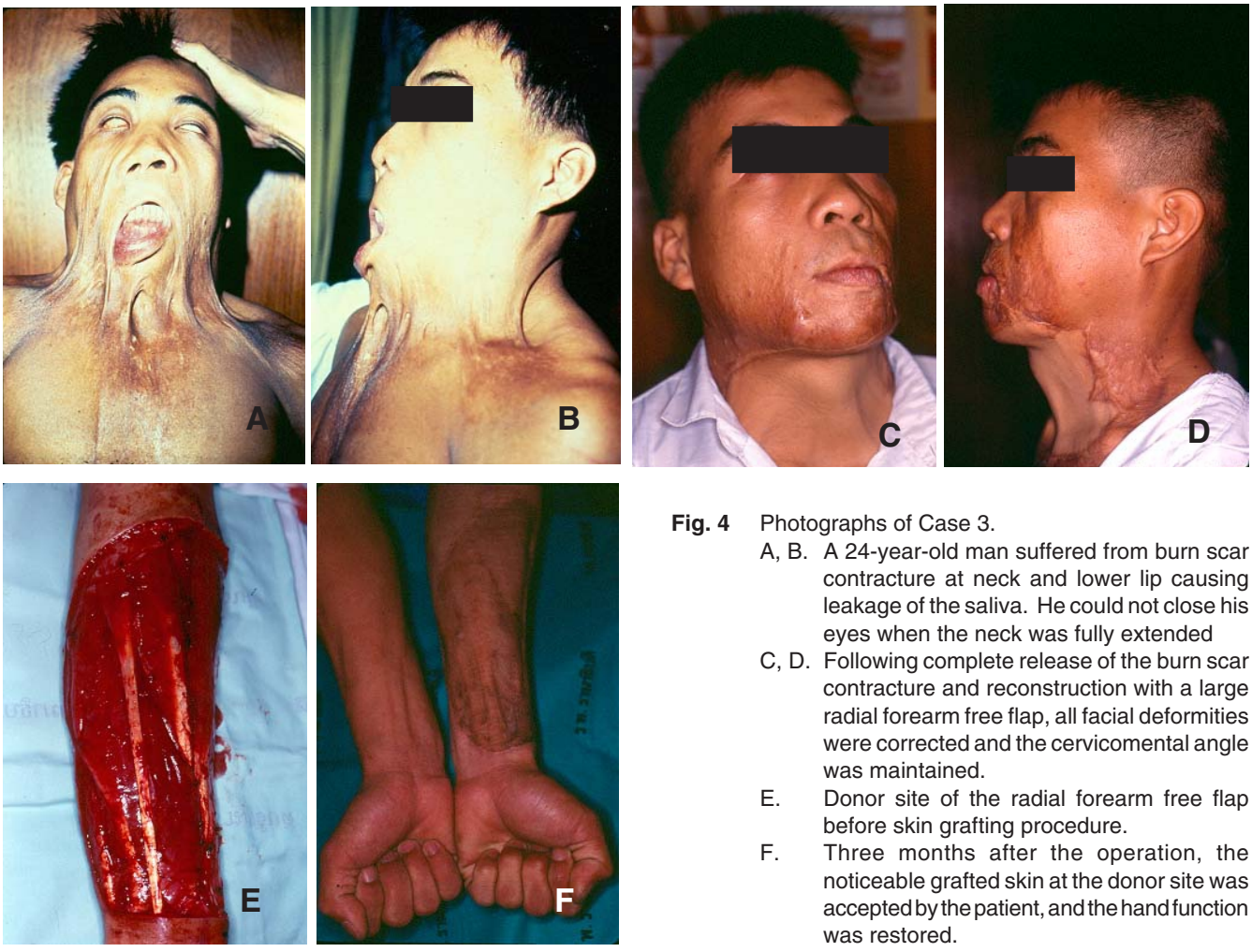


Fig. 4 Photographs of Case 3.
A, B. A 24-year-old man suffered from burn scar contracture at neck and lower lip causing leakage of the saliva. He could not close his eyes when the neck was fully extended
C, D. Following complete release of the burn scar contracture and reconstruction with a large radial forearm free flap, all facial deformities were corrected and the cervicomental angle was maintained.
E. Donor site of the radial forearm free flap before skin grafting procedure.
F. Three months after the operation, the noticeable grafted skin at the donor site was accepted by the patient, and the hand function was restored.

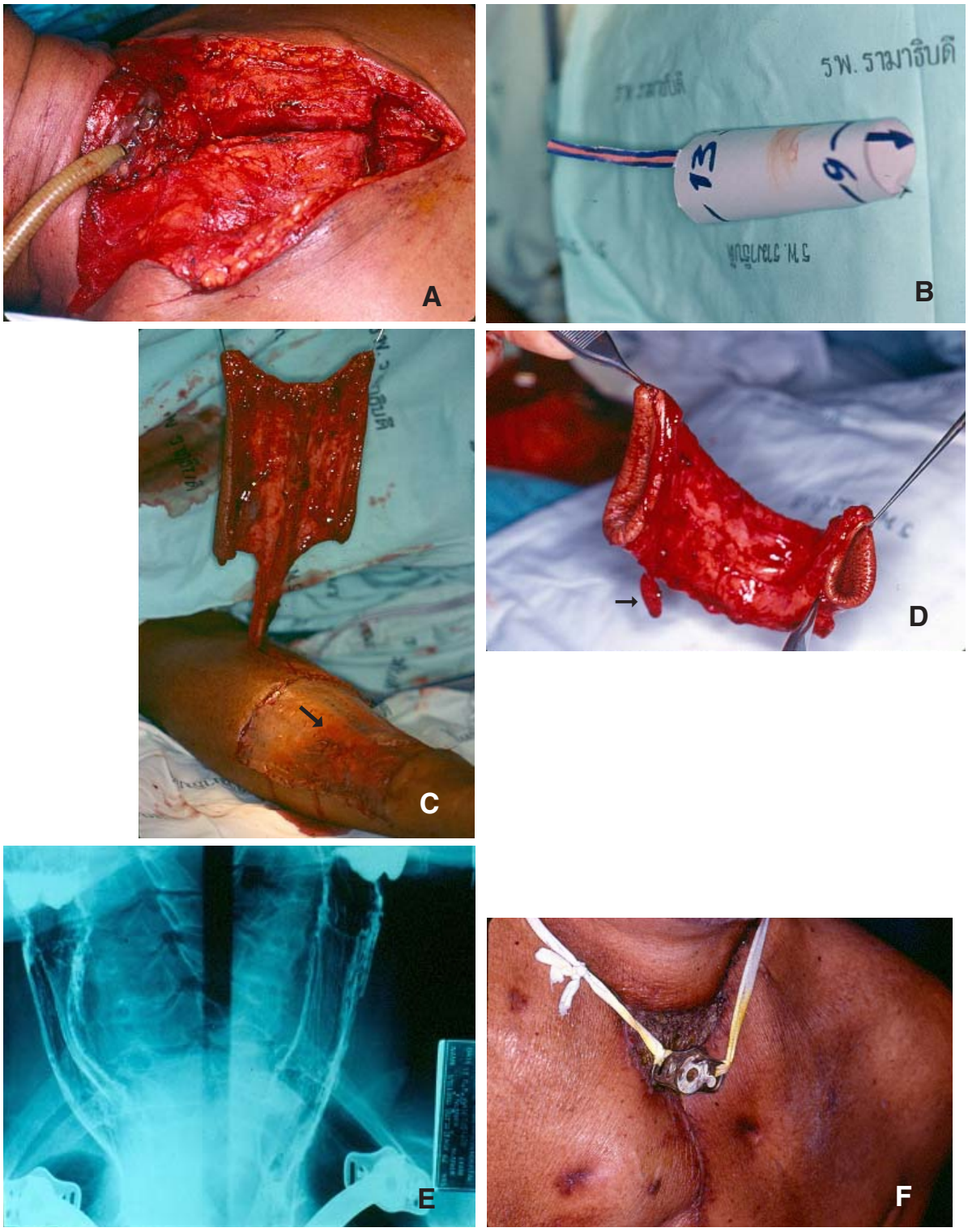


Fig. 5 Photographs of Case 4.

A. An esophageal defect measured 10 cm long following segmental resection of a cancer.
B. A flap pattern was made for esophagus reconstruction. The proximal and distal diameter were 13 and 9 cm respectively.
C. A radial forearm island flap was developed, and the donor site (arrow) was skin grafted.
D. A tubing of the radial forearm free flap was tailored - made for reconstruction of the esophagus. The arrow was the radial artery with its venae comitantes.
E. Two weeks after the procedure, barium swallow revealed patency of the reconstructed esophagus.
F. Three weeks after the operation, the wound healed with no complications.

Case 5 (Figure 6)

A 51-year-old man presented with a chronic venous ulcer at right medial malleolar region. It failed to respond to any medical or previous surgical treatments. The surgical treatment with a free flap was suggested to the patient and he accepted it. The ulcer was completely excised, and the posterior tibial vessels were used for recipient artery and vein (deep vein). A radial forearm fasciocutaneous free flap measuring 7×9 cm in diameter was designed to form a flow-through free flap for immediate coverage and concurrent limb revascularization. In this condition, the blood supply to the foot via posterior tibial artery would not be disturbed. Following the free flap procedure, the foot was kept elevated above the heart level to help increase venous return. The post-operative result was successful and there has been neither complications nor recurrence of the venous ulcer.

Case 6 (Figure 7)

A 62-year-old man, a betel nut chewer, suffered from an extensive carcinoma of the gum with foul smell. At first visit, he denied surgical treatment, but he finally came back five months later because of pain and trismus. On examination, the tumor was nearly invading the cheek skin. Further investigations revealed no evidence of distant metastasis except the ipsilateral multiple cervical lymph nodes enlargement. A commando operation was performed together with an immediate total reconstruction using a tailor-made radial forearm osteomusculofasciocutaneous composite free flap i.e. two skin paddles for intra-oral lining and cheek skin coverage, a segment of radius for hemimandibular reconstruction, and a palmaris longus tendon for suspension of the left angle of mouth. The post-operative course was uneventful and one month later he received post-operative adjuvant radiotherapy.

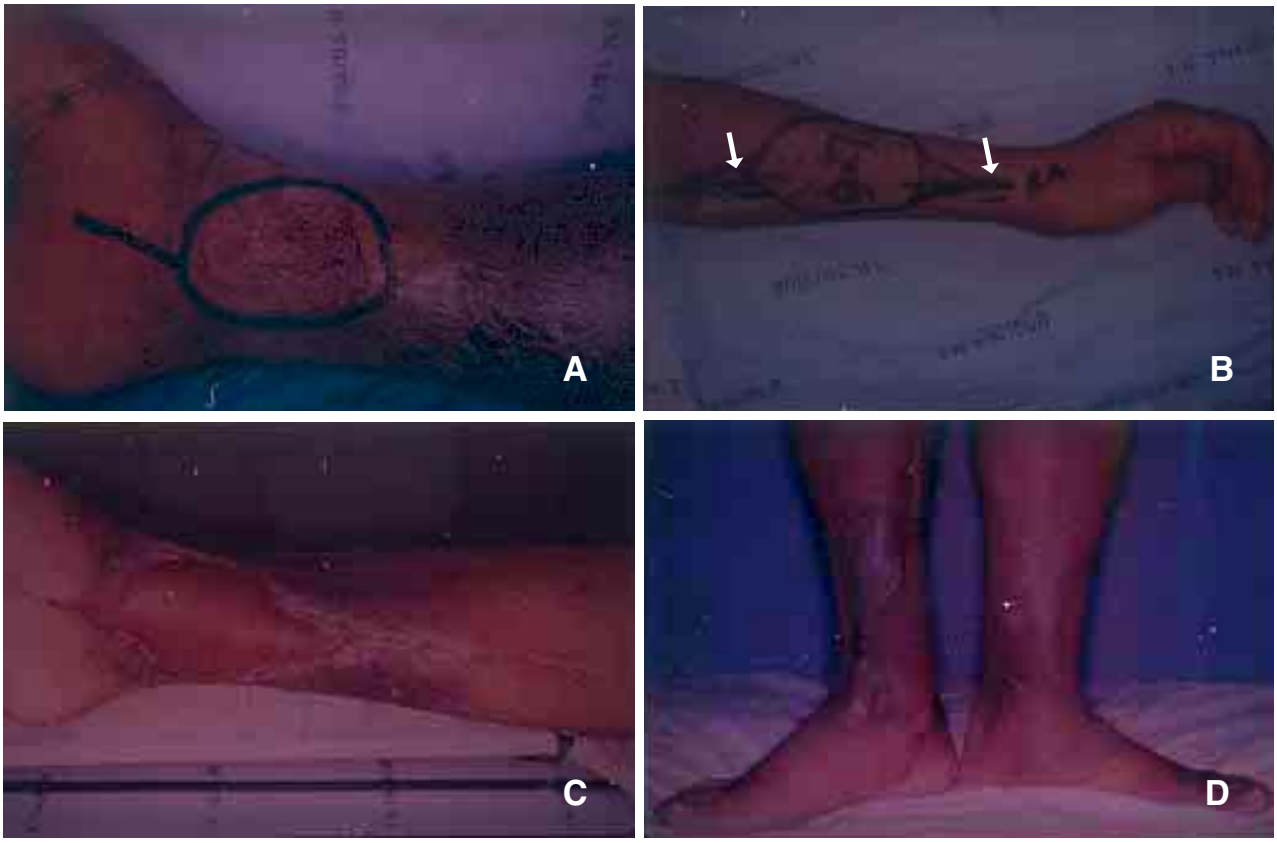
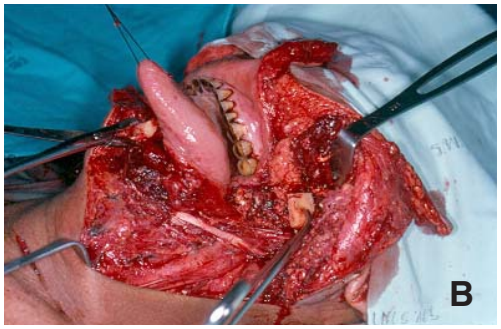
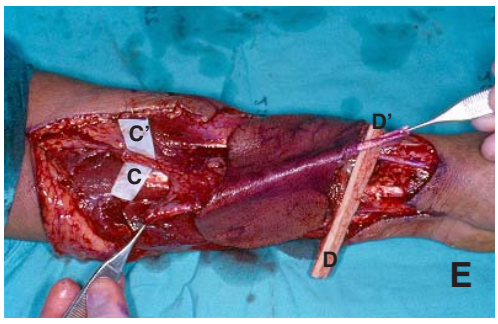


Fig. 6 Photographs of Case 5.
A. Chronic venous ulcer was completely excised. The posterior tibial vessels were identified proximally and distally.
B. A radial forearm free flap was designed to form a flow-through flap when both ends of the radial artery (arrows) were anastomosed to both ends of the posterior tibial artery.
C. Two weeks after the operation, the foot was elevated above the heart level and the flap healed without any complications.
D. Post-operative picture at 5 months after the surgery, there has been no recurrence of the venous ulcer.

Fig. 7 Photographs of Case 6.

A. A 62-year-old man suffered from extensive CA gum (T4, N3, M0).
B. Intra-operative picture following a commando operation, two bone clamps were holding both ends of the mandible to be reconstructed.
C. The wound was closed according to anatomical approximation and a through-and-through defect of oral mucosa, cheek skin, and mandible was seen.
D. A tailor-made radial forearm osteomusculofasciocutaneous free flap was designed for total reconstruction. Two skin paddles both measured 5x8 cm were used for intra-oral lining and skin cover; and a segment of radius for hemimandibular reconstruction.
E. Intra-operative picture, two Adson forceps were holding palmaris longus tendon which was used for suspension of left angle of the mouth to left zygomatic bone. CC' was a radial artery with its venae comitantes. DD' was a segment of radius.
F. A composite free flap had been harvested. The radius was osteotomized and immobilized with a plate and screws to form a desired contour of the mandibular defect. The skin flap was deepithelialized (arrows) to become two skin paddles. PL was a palmaris longus tendon. RA was radial artery and its venae comitantes. V was superficial vein.
G. Following an inset of the composite free flap, rigid bony fixation was first carried out before microvascular anastomoses of one artery and two veins. The upper arrow was a skin island for mucosal lining and the lower one was for facial skin.
H., I. One month after the operation, the free flap including the vascularized radius was well-tolerated to post-operative radiotherapy.





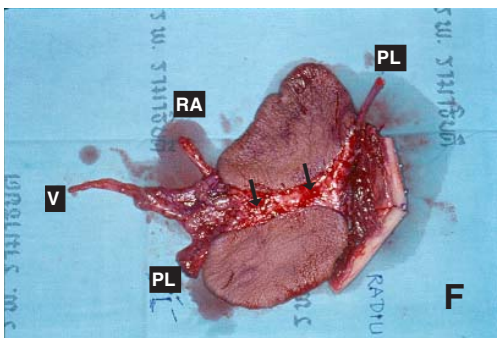


Table 2 Higher free flap success rate after the "learning curve"

Author	Year of report	Experience	Success rate
Serafin[21]	1980	First 25 cases / last 25 cases	72% / 96%
Godina[22]	1986	First 100 cases / last 100 cases	72% / 96%
Harsashina[20]	1988	First 3 years / last 5 years	75% / 97%
Khouri, Shaw[23]	1989	First 100 cases / last 100 cases	91% / 97%
Salemark, et al[24]	1991	3,694 cases from 30 centers	96%
Kruavit, et al[14]	1998	177 cases in 10 years	96.06%

It should be noted that this case was out of consecutive series of 49 cases of RFFFs performed during September 1986-September 1996, but the purpose of this presentation was to demonstrate the advantages of a radial forearm osteomusculofasciocutaneous composite free flap for one-stage reconstruction of a three dimensional and composite facial defect.

Discussion

Free flap procedure has become a gold standard in reconstructive plastic surgery. The success rates following the "learning curves" are over 95 per cent[14,19-24] (Table 2) and the esthetic and functional results are superior to other conventional techniques. It is said that free flap is the reconstructive method of choice for defect in all areas of the body especially for a complex tissue defect, a difficult wound, and a three dimensional defect. Over the past two decades, free flap procedure has progressed from being scientific curiosities to everyday workhorse technique. It is now routinely performed not only on an elective patient but also in urgent situation as emergency free flap or early free flap. When indicated, a free flap is now a preferred method for transfer of distant tissue. At present, there are more than 50 free flaps of various components and designs to fulfil the reconstructive need or to replace "like with like" for reconstruction in all areas of the body. Among them, we have found that RFFF has become the workhorse because of its large size with thin and pliable skin of the flap even in an obese patient. Furthermore, the RFFF is easy to dissect with a constant anatomy. Long vascular pedicle and large veins of 2-3 mm in diameter of both superficial and deep veins make safe for microvascular anastomoses without interposition vein graft and more than one venous anastomosis can be achieved to solve the problem of post-operative venous congestion.

The forearm provides a relatively pain-free donor site which does not increase the post-operative morbidity or restriction during early post-operative mobilization. Delayed soft tissue healing, should it occur, does not significantly alter the patient's post-operative course and to date there have been no problems in regaining full hand and wrist functions. As we all know that as far as the dual blood supply system of the hand is concerned, radial artery is the dominant blood supply of the radial digits, its harvesting may cause greater circulatory disturbances in radial digits than in ulnar digits.[25] This major disadvantage of the RFFF, namely the disruption of the radial artery supply to the hand, can be easily overcome by the immediate insertion of an interpositional vein graft, but this is not necessary if the Allen's test performed before the procedure has revealed adequate blood supply from ulnar artery to the whole hand. All patients in this report as well as others[26,27] have had no problem with cold intolerance or ischemia. Furthermore, cardiothoracic surgeons[28-31] have been using a radial artery for coronary artery bypass grafting (replace like with like) which is definitely better than a vein graft, and found that there was no significant difference between the operated and nonoperated hands in vascular and hand function studies. In fact, radial artery harvesting may have a lesser effect on blood circulation of the hand than does RFFF. This is because during the harvest of radial artery for coronary bypass, the forearm skin and veins are not removed and the cutaneous nerves are not exposed or cut. But on the basis of our experience and others as mentioned above, we conclude that pre-operative Allen's test is useful for reassuring adequate hand blood supply

from the ulnar artery and RFFF can be safely performed without functional problems attributed to hemodynamic disorders, even in the early post-operative period.

The other main criticism of the RFFF is the donor site defect, which requires skin graft that may produce a contour deformity especially in a young woman. This concern is directly related to the design of the flap; but the advantages of this method of reconstruction greatly outweigh esthetic considerations. Apart from this, frequent problems or complications[32,33] of the donor sites are skin graft failure, skin graft and tendon adhesions, fracture of the radius, and probably dysesthesia secondary to superficial radial nerve injury, all of which cause functional problems. Donor site morbidity is only one of a number of factors affecting the choice of flap used in reconstruction. With regards to the RFFF, experience has shown that donor site problem can be avoided if meticulous flap dissection is employed. In our experience, there was only one old lady patient having post-operative fracture of the residual donor radius which subsequently healed after closed reduction and forearm slab immobilization. Several techniques for prevention of the donor site problems have been reported and recommended by many authors.[34-39]

One advantage in elevation of the RFFF is straightforward and may be performed simultaneously with the excision of the head and neck lesion or preparing the recipient defect of the lower extremity, without altering the patient's position on the operating table. On the contrary, other free flaps may have the disadvantage in the difficulty in positioning the patient. Additional advantage of the RFFF is the possibility of including a portion of radius, tendons (PL, FCR[40]), and cutaneous nerves of the forearm for specific need of reconstruction in one-stage procedure as a composite free flap. Although small, the segment of radius is quite strong and will accept osseointegrated implants for dental rehabilitation.[41] However, as far as composite mandibular reconstruction is concerned, the stronger fibular osteoseptocutaneous free flap has been reported to be an ideal method of choice.[42,43] A reversed flow of osteocutaneous RFF was reported as composite island flap for total thumb reconstruction.[6] To keep the forearm skin intact, the radial forearm fascial free flap can be used for reconstruction and recently RFFF with adipofascial tissue extension was reported for reconstruction of oral cancer defect.[44]

In regard to utilizing a RFFF, the successful outcomes depend on several factors:

Firstly, the experience of microvascular surgeon with his knowledge of flap anatomy and skill in flap dissection was cited as the most important single factor contributing to success of the free flap procedure.[20-23] The important steps of flap dissection especially the vascular pedicle and the critical point of proper microvascular anastomoses should be performed only by the experienced faculty staff surgeon under the operating microscopic vision, not by surgical resident in training. Practise to obtain enough skill and confidence in doing microvascular anastomosis and flap dissection should untilize animal models and the cadavers specimen.

Secondly, the microvascular surgeon's choice of flap donor site has a significant effect on the probability of flap survival, and not all free flaps are equal.[45] When selecting a free flap for a given defect, the microvascular surgeon should consider the ease of flap execution as one factor determining flap choice, especially if one is relatively not soexperienced. If all other factors are equal, the flap with the lowest failure rate will ordinarily be the best and reliable selection. Our experience has shown that the RFFF, which has a constant anatomy, is an ideal and a reliable flap and it should be the first free flap to start with for a beginning microvascular surgeon who just starts doing free flap surgery.[14] Whenever possible, one should try to avoid more difficult free flaps. Thus, the groin flap, the earliest free flap, is rarely used today because it has a small, short vascular pedicle, and also unreliable vasculature. Serafin, et al[21] reported a comparable failure rate of 23 per cent (7/30) in their groin free flaps, but only a 5 per cent failure rate in their latissimus dorsi musculocutaneous free flaps. The other factor that adversely affected flap survival in our study was the use of vein grafts. It had been shown that latissimus dorsi musculocutaneous flaps that required one-stage interposition vein grafts had a statistically significant higher rate of flap loss than did flaps that did not require interposition vein grafts.[14] This problem did not happen in our use of RFFF.

Thirdly, a good teamwork who helps look after the patient post-operatively. The credit must be given to the surgical residents and nurses because no monitoring devices, which were costly in our country,

had been used to assess post-operative blood flow; instead only clinical signs (skin color and turgor, capillary refill, and needle puncture under aseptic technique) were regularly monitored. A report of international survey in 1991 showed that the majority of microsurgical centers worldwide still rely on clinical signs for routine monitoring of blood flow in free flap transfers and replantations.[24] If a careful and intelligent post-operative program is employed for early detection of the vascular compromise, it is rarely necessary to return the patient to the operating room for reexploration. However, if either arterial inflow or venous outflow is questionable, the patient should be immediately returned to the operating room for revision or reanastomosis with or without necessary medical treatment. Since this aggressive approach has been started with no "wait and see" policy for a free flap surgery, all failing free flaps can be saved otherwise they would be lost. If this decision is made, however, it must be carried out as soon as possible within 4 to 6 hours of the loss of adequate tissue perfusion especially of the muscle free flap which its warm ischemic time is shorter than cutaneous free flap.[46] It was well accepted that signs of arterial or venous thrombosis should be recognized immediately and dealt with promptly in order to save a failing free flap before the "no reflow phenomenon", the end-point of critical ischemia, develops[47,48] or before the occurrence of fatal thromboses. All of our six failing radial forearm fasciocutaneous free flaps were treated or reexplored within 24 hours after early detection of vascular compromise and all were successfully salvaged.

Finally, for esophagus reconstruction where the flap was hidden under the anterior chest wall, it was impossible to detect flap viability by clinical signs. As such, the monitoring devices are essential to achieve a high success rate.[22] Fortunately, all three esophagus reconstructions with RFFFs in our experience had no complications in spite of no monitoring devices.

Thus, we would suggest that RFFF should be the first free flap for those who are doing microsurgery to start with to achieve a success of free flap procedure.

Conclusion

The loss of a free flap is devastating to both the patient and the microvascular surgeon. Based on the authors' early experience of 49 consecutive successful clinical cases, the radial forearm free flap appears to offer a safe, reliable, versatile, and ideal method especially for head and neck, and lower extremity reconstruction. More important to our discipline is the good and necessary judgement to select the proper free flap donor site including adequate preparation and isolation of reliable recipient vessels. It is a very valuable tool in the armamentarium of reconstructive microvascular surgeon who should try, whenever possible, to avoid the more difficult flaps.

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