Lower Extremity Reconstruction with Vascularized Free-Tissue Transfer: 20 Years of Experience in the Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand

Nutthawut Akaranuchat, M.D.

Division of Plastic Surgery, Department of Surgery, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.

ABSTRACT

Objective: The reconstruction of extensive soft-tissue defects in the lower extremity still poses a great challenge to plastic and reconstructive surgeons. The ideal approach is to achieve a proper soft-tissue coverage with a well-vascularized flap, which results in a durable weight-bearing surface and permits normal joint motion. This study aims to retrospectively analyze the outcomes of lower-extremity reconstruction with vascularized free-tissue transfer performed at our plastic surgery division.

Materials and Methods: A retrospective chart review was performed regarding 58 patients with defects in the lower extremity which were reconstructed with vascularized free-tissue transfers between 2000 and 2019. Forty-four of the patients were male, and 14 were female. The mean age was 44.4 years (range: 6-89 years). The most common indication for free-flap surgery was a secondary reconstruction after tumor eradication (23 cases, 39.7%), and 84.8% of the defects were exposed bare bones, tendons, or joints.

Results: In our 58 reviewed cases, the foot was the most common area requiring reconstruction with a free flap (68.9%), and the mean defect size was 12.5 x 8.1 cm. The most commonly used free flap was the Anterolateral thigh free flap (39.7%), followed by the Gracilis free flap (29.3%), and the Superficial circumflex iliac artery-perforator free flap (10.4%). The recipient vessels most frequently used were posterior tibialis vessels (53.4%). The overall flap-survival rate was 75.9%, though there was an increased survival rate of up to 85.7% in the last five years of the period studied. The flap-salvage rate was 40.9%, and arterial thrombosis was the major cause of flap loss (50%). Factors associated with free-flap failure were re-exploration and free flap surgery after tumor or cancer eradication. The most common post-operative complication was flap-wound dehiscence (10.3%). Two patients received a flap correction due to bulkiness, and three had recurrence of ulceration.

Conclusion: Microvascular free-tissue transfers for lower- extremity-defect reconstructions are reliable and valuable as a surgical technique. In 20 years of experience, we've had an overall flap survival rate of 75.9%. Factors associated with free-flap failure were re-exploration and free flap surgery after tumor or cancer eradication. And our flap of choice was the Anterolateral thigh free flap.

Keywords: Lower extremity reconstruction; foot reconstruction; free flap; microsurgery; flap surgery (Siriraj Med J 2021; 73: 462-470)

Corresponding author: Nutthawut Akaranuchat
E-mail: nutthawut.aka@mahidol.ac.th, nutthawut.joe@gmail.com
Received 23 November 2020 Revised 17 March 2021 Accepted 19 March 2021
ORCID ID: https://orcid.org/0000-0003-1798-8484
http://dx.doi.org/10.33192/Smj.2021.60

INTRODUCTION

Microvascular free-tissue transfers have become the preferred reconstructive technique to manage complex wounds and surgical defects after an ablative procedure, as the result of trauma. It is also the preferred technique to deal with special-requirements situations such as facial reanimation with a functioning muscle transfer in facial-palsy patients. There have been numerous clinical reports on free-tissue transfer since the microvascular technique was introduced in the early 1960s.[1-5] Previous data demonstrate that microvascular free-tissue transfers allow for reliable, single-stage, and immediate reconstruction involving more complex defects from various etiologies.[6-17] Many case series have also reported a high flap-success rate.

To date, reconstruction of extensive soft-tissue defects in the lower extremity still poses a great challenge to reconstructive surgeons. A defect on the lower limb will require some form of reconstruction in the majority of cases. Also, permanent scar formation after tight closure or after skin grafting or inadequate local flap use can result in pain and unstable wounds when a person is bearing weight. Thus, the ideal approach to treating a lower-limb defect is to achieve proper soft-tissue coverage with a well-vascularized flap, which results in a durable weight-bearing surface and permits normal ankle motion.[18] There is no debate that only free flaps can cover extensive soft tissue defects and provide satisfactory functional outcomes without amputation.[19,20]

At our institute, we started performing free-flap reconstruction for defects in the lower extremities in1992, but we had not collected the data nor had we evaluated the final outcomes after surgery. This study aims to retrospectively analyze the outcomes of lower-extremity reconstruction with vascularized free-tissue transfer performed at the Division of Plastic Surgery, Department of Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University.

MATERIALS AND METHODS

A retrospective chart review was conducted regarding all patients who underwent free-flap surgery for lower-extremity defect reconstruction at the Division of Plastic Surgery, Department of Surgery, Faculty of Medicine Siriraj Hospital from January, 2000 to December, 2019. The age, gender, underlying disease, other risk factors (smoking, obesity, etc.), American Society of Anesthesiologists (ASA) classification, indication for surgery, location of defect, type of flap, operative time, inflow and outflow vessels, type of anastomosis, vein-graft usage, ischemic time, length of hospital stay, length of intensive-unit stay, flap-success rate, re-exploration surgery, salvage rate, and perioperative complications of all the patients were recorded. These data were collected in a database and were available for statistical analysis.

Data assessment

The total operative time was defined as the time between the first incision and the wound closure. The ischemic time was defined as the time from the transection of the vascular pedicle to a complete arterial anastomosis and then the release of the vascular clamp. The flap-success rate was defined as complete flap viability or partial flap loss that still achieved the primary indication of surgery.[18] Complications were divided between flap- related and general complications.

Statistical analysis of the data was performed using the Statistical Package for the Social Sciences (SPSS). The chi-square and Fisher's exact test were used to statistically compare variables that influence the flap-success rate and perioperative complications. A p-value of 0.05 or less was regarded as statistically significant.

RESULTS

Between January 2000 and December 2019, 58 microvascular free-tissue transfers for lower-extremity reconstruction were performed to cover and/or reconstruct various kinds of defects and diseases. There were 44 men and 14 women ranging in age from 6 to 89 years (mean: 44.4 years). Most of the cases involved a body mass index (BMI) from 18.5-22.9 kg/m^2 (32.7%). Ten of the 58 patients had underlying type 2 diabetic mellitus. The three most common areas in the lower extremity that needed reconstruction with a free flap were 1: a foot (40 of 58, 68.9%), 2: a leg (14 of 58, 24.1%) and 3: an ankle (5 of 58, 8.6%). Also, the plantar hind foot was the most common area of the foot that needed coverage (18 0f 58, 31.1%). Among the 58 patients, there were 23 defects (39.7%) caused from tumor eradication, 19 defects (32.8%) due to trauma, and 8 defects (13.8%) resulting from post-operative debridement due to severe soft-tissue infection. Fifty-five of the 58 cases (84.8%) were defects that exposed bare bones, bare tendons, or joints.

Seventy percent of the defects were between 5-15 cm. (41 of 58, 70.7%); the mean defect size was 12.5 x 8.1 cm. (a range from 3-26 cm.). The three most common flap types for reconstructing a lower-extremity defect were the Anterolateral thigh (ALT) free flap (23 of 58, 39.7%), followed by Gracilis free flap (17 of 58, 29.3%), and the Superficial circumflex iliac artery perforator (SCIP) free flap (6 of 58, 10.4%). The recipient arteries frequently

used for anastomosis were the posterior tibialis artery (31 of 58, 53.4%), the anterior tibialis artery (11 of 58, 19%), and the dorsalis pedis artery (8 of 58, 13.8%). More than 70% (45 of 58) of the cases were performed with one artery and one vein anastomosis, and 75.9% (44 of 58) of the patients had an arterial anastomosis with the end-to-end anastomotic technique (end to side, 24.1%). Most of the cases resulted, primarily, in a closing of the donor-site defect (42 of 58, 72.4%). (Table 1)

The mean duration of the total operative time (including surgical resection) was 520 minutes (range: 330-960 minutes). The mean flap harvesting time was 76 minutes (range: 40-120 minutes). The mean ischemic time was 59 minutes (range: 36-115 minutes). (Fig 1)

For post-operative outcomes, the overall flap-survival rate was 75.9% (44 of 58 patients). Re-exploration for anastomosis revisions was performed in 22 of 58 cases (37.9%), with a flaps-salvaging success rate of 40.9% (9 of 22 cases). The most common cause of flap revision was venous congestion (11 of 22 cases, 50%), but the most common cause of total flap failure was arterial thrombosis (7 of 14 cases, 50%). The recipient-site complications included wound dehiscence (6 of 58 cases, 10.3%), surgical-site infection (4 of 58 cases, 6.9%), and skin-graft loss (4 of 58 cases, 6.9%). Donor-site complications were found in 8.6% of patients, and the most common complication was wound dehiscence (2 of 58 cases, 3.5%). (Table 2)

Due to advances in microsurgical techniques and the better quality of microscopes and other instruments, the outcomes of lower-extremity reconstruction were significantly better than previous outcomes. In our institute, the overall free-flap survival rate rose from 66.7% (2000-2014) to 85.7% (2015-2019). Some microsurgeons have performed a more sophisticated flap to serve the specific requirements of the patient with the aim of restoring both the function and the appearance. (Table 4)

DISCUSSION

A major development in the reconstruction of defects in various locations was the introduction of free vascularized tissue transfer in the 1960s and 1970s, which enabled primary reconstruction of more complex and extensive defects. Our retrospective study presents our staff's experience in performing 58 microvascular free-tissue transfers for lower- extremity reconstruction over the last ten years, and it revealed a success rate of 75.9%. The majority of defects were connected to tumor ablative surgery and were between 5-15 cm. in the largest dimension. A gracilis muscle free flap with skin grafting was frequently done in the past, but the ALT free flap is our free flap of choice for lower-extremity reconstruction, due to its harvesting in a very large flap size, its long pedicle length, its low donor-site morbidity, and its modifications, such as enabling the inclusion of fascia or muscle into the flap.[21] The re-exploration rate in our series was 37.9%, with a salvage rate of 40.9%, which is quite low when compared to results from other studies.[22-24] In the last five years, the flap-salvage rate has significantly improved, from 16.7% (2000-2014) to 70% (2015-2019). (Tables 3 and 4)

Factors that influence flap failure and associated complications continue to be debated. Reported factors related to flap failure are the pre-operative status of the patient, his or her age, smoking, pre-operative radiation, flap type, surgical expertise, use of a vein graft, operative time, and re-exploration for anastomosis revision; however, we still do not have sufficient prospective data to definitively identify all of the significant causes. The factors related to wound complications and general complications were age, ASA class, diabetes mellitus, pre-operative radiation, smoking, and alcohol consumption, but there remains a lack of prospective data to definitively identify all of the significant causes.[7,14,25-29]

For our report, re-explorative surgery and free flap surgery after tumor or cancer eradication were significant factors vis a vis total flap failure. The failure rate of free-flap surgery significantly decreased commensurate with the increase in surgical expertise. (Tables 3 and 4)

CONCLUSION

Microvascular free-tissue transfers are reliable and valuable as a surgical technique in achieving successful lower- extremity defect reconstructions. At our institute, we began performing free-flap reconstruction for defects in the lower extremities in 1992. For the past 20 years, the overall flap-survival rate was 75.9% (44 of 58 cases); the re-exploration rate was 37.9% (22 of 58 cases); and the rate of successfully salvaging flaps was 40.9% (9 of 22 cases). The anterolateral thigh free flap was the flap of choice in our lower-extremity defect reconstruction. The most commonly used recipient vessels were the posterior tibialis artery and vein. In our institute's experience, the key factors associated with lower extremity free-flap failure were re-exploration and free flap surgery after tumor or cancer eradication. Finally, this study presents 20 years of experience and surgical outcomes in lower-extremity defect reconstruction with vascularized free-tissue transfers at the Division of Plastic Surgery, Department of Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University. These results present a current baseline for lower-extremity free-flap surgery to which future advances in technique and practice may be compared.

TABLE 1. Patients' demographic and clinical data.

Characteristics	
Number of patients	58
Mean age, year (range)	44.4 (6-89)
Sex, male (%): female (%)	44 (75.9%): 14 (24.1%)
Body mass index, BMI (%)	
<18.5	11 / 58 (19.0%)
18.5 - 22.9	19 / 58 (32.7%)
23.0 - 24.9	12 / 58 (20.7%)
25.0 - 29.9	15 / 58 (25.9%)
30 - 40	1 / 58 (1.7%)
40.1 - 50	no
>50	no
ASA classification	
Class I	38
Class II	9
Class III	10
Class IV	1
Underlying disease	
Diabetic mellitus no. (%)	10 / 58 (17.2%)
Smoking no. (%)	7 / 58 (12.1%)
Peripheral arterial disease no. (%)	5 / 58 (8.6%)
Hypertension no. (%)	8 / 58 (13.8%)
Dyslipidemia no. (%)	3 / 58 (5.2%)
Paraparesis or paraplegia	2 / 58 (3.4%)
Hemiparesis or hemiplegia	1 / 58 (1.7%)
Tumor or cancer	2 / 58 (3.4%)
Chronic renal failure	1 / 58 (1.7%)
Defect site no. (%)	
Thigh	1 / 58 (1.7%)
Knee	3 / 58 (5.2%)
Popliteal fossa	no
Leg	14/58 (24.1%)
Proximal third leg	no
Middle third leg	1 / 58 (1.7%)
Distal third leg	2 / 58 (3.4%)
Proximal and middle third leg	no
Middle and distal third leg	3 / 58 (5.2%)
Proximal, Middle and distal third leg	3 / 58 (5.2%)
Ankle	5 / 58 (8.6%)
Foot	40/58 (68.9%)
Dorsal of foot	7 / 58 (12.1%)
Plantar forefoot	4 / 58 (6.9%)
Plantar midfoot	2 / 58 (3.4%)
Plantar hindfoot	18 / 58 (31.1%)
Plantar forefoot and midfoot	3 / 58 (5.2%)
Plantar midfoot and hindfoot	5 / 58 (8.6%)
Plantar forefoot, midfoot and hindfoot	1 / 58 (1.7%)

Defect size no. (%)	
Small defect (<5 cm)	3 / 58 (5.2%)
Medium defect (5-10 cm)	22 / 58 (37.9%)
Large defect (10.1-15 cm)	19 / 58 (32.8%)
Very large defect (15.1-20 cm)	8 / 58 (13.8%)
Giant defect (>20 cm)	6 / 58 (10.3%)
Etiology no. (%)	
Trauma	19 / 58 (32.8%)
Tumor or cancer eradication	23 / 58 (39.7%)
Infection	8 / 58 (13.8%)
Ischemic ulcer	2 / 58 (3.4%)
Venous ulcer	no
Diabetic ulcer or neuropathic ulcer	4 / 58 (6.9%)
Irradiation	no
Unstable scarring	2 / 58 (3.4%)
Exposure to bone, tendon, or joint no. (%)	55 / 58 (84.8%)
Mean defect size (Length x width, cm)	12.5 x 8.1 cm (Range 3-26 cm)
Flap source artery no. (%)	
Branch of lateral circumflex femoral artery	3 / 58 (5.2%)
Popliteal artery	no
Posterior tibialis artery	31 / 58 (53.4%)
Medial plantar artery	3 / 58 (5.2%)
Anterior tibialis artery	11 / 58 (19.0%)
Dorsalis pedis artery	8 / 58 (13.8%)
Peroneal artery	1 / 58 (1.7%)
Lateral supramalleolar artery	1 / 58 (1.7%)
Number of anastomosis no. (%)	
1 artery:1 vein	45 / 58 (77.6%)
1 artery:2 vein	13 / 58 (22.4%)
Type of arterial anastomosis no. (%)	
End to end	44 / 58 (75.9%)
End to side	14 / 58 (24.1%)
Free flap no (%)	
ALT free flap	23 / 58 (39.7)
VL free flap	1 / 58 (1.7%)
Latissimus dorsi free flap	3 / 58 (5.2%)
Gracilis free flap	17 / 58 (29.3)
MSAP free flap	4 / 58 (6.9%)
SCIP free flap	6 / 58 (10.4%)
Radial forearm free flap	1 / 58 (1.7%)
Parascapular free flap	1 / 58 (1.7%)
Internal oblique muscle free flap	1 / 58 (1.7%)
Temporoparietal fascial free flap	1 / 58 (1.7%)
Flap composition no. (%)	
Fasciocutaneous flap	34 / 58 (58.6%)
Muscle flap	18 / 58 (31.1%)
Musculocutaneous flap	4 / 58 (6.9%)
Fascial flap	1 / 58 (1.7%)
Osteocutaneous flap	1 / 58 (1.7%)
Donor-site closure no (%)	
Primary closure	42 / 58 (72.4%)
STSG	16 / 58 (27.6%)

Abbreviations: ASA = American Society of Anesthesiologists; ALT = Anterolateral thigh; VL = Vastus lateralis; MSAP = Medial sural artery perforator; SCIP = Superficial circumflex iliac artery perforator; STSG = Split-thickness skin graft

Fig 1. Left plantar midfoot defect after tumor eradication. The defect was reconstructed with superficial circumflex iliac artery perforator free flap which harvested from left groin area. Donor site defect was closed primarily. Inset flap was done and the microvascular anastomosis was performed with lateral plantar vessels.

TABLE 2. Post-operative surgical outcomes.

Flap survival no. (%)	44 / 58 (75.9%)
Flap loss no. (%)	
Partial loss no. (%)	11 / 58 (19.0%)
Complete loss no. (%)	14 / 58 (24.1%)
Arterial thrombosis no. (%)	7 / 14 (50.0%)
Venous thrombosis no. (%)	6 / 14 (42.9%)
Hypercoagulable stage no. (%)	1 / 14 (7.1%)
Flap revision no. (%)	22 / 58 (37.9%)
Arterial insufficiency no. (%)	10 / 22 (45.5%)
Venous congestion no. (%)	11 / 22 (50%)
Bleeding hematoma	1 / 22 (4.5%)
Flap salvage no. (%)	9 / 22 (40.9%)
Recipient site complication no. (%)	19 / 58 (32.8%)
Infection no. (%)	4 / 58 (6.9%)
Dehiscend wound no. (%)	6 / 58 (10.3%)
STSG loss no. (%)	4 / 58 (6.9%)
Hematoma no. (%)	2 / 58 (3.5%)
Seroma no. (%)	no
Donor site complication no. (%)	5 / 58 (8.6%)
Infection no. (%)	1 / 58 (1.7%)
Dehiscend wound no. (%)	2 / 58 (3.5%)
STSG loss no. (%)	1 / 58 (1.7%)
Hematoma no. (%)	no
Seroma no. (%)	1 / 58 (1.7%)
Flap correction	
Debulging no. (%)	2 / 44 (4.5%)
Recurrent ulcer no. (%)	3 / 44 (6.8%)

TABLE 3. Data comparisons between the group of flap success and flap failure.

Comparative data	Flap success (%)	Flap failure (%)	p-value
Case	44 (75.9%)	14 (24.1%)	0.165
Year 2000-2014	20 (66.7%)	10 (33.3%)	
Year 2015-2019	24 (85.7%)	4 (14.3%)	
Sex			0.931
Male	33 (75%)	11(25%)	
Female	11(78.6%)	3 (21.4%)	
ASA classification			**0.913**
Class I	29 (76.3%)	9 (23.7%)	
Class II	7 (77.8%)	2 (22.2%)	
Class III	7 (70%)	3 (30%)	
Class IV	1 (100%)	0 (0%)	
Cause			
Trauma	17 (89.5%)	2 (10.5%)	0.173
Tumor or cancer eradication	13 (56.5%)	10 (43.5%)	0.013*
Infection	7 (87.5%)	1 (12.5%)	0.701
Ischemic ulcer	2 (100%)	0 (0%)	0.977
Diabetic ulcer or Neuropathic ulcer	3 (75%)	1 (25%)	0.573
Unstable scarring	2 (100%)	0 (0%)	0.977
Underlying disease			
Diabetic mellitus no. (%)	7 (70%)	3 (30%)	0.944
Smoking no. (%)	6 (85.7%)	1 (14.3%)	0.858
Peripheral arterial disease no. (%)	4 (80%)	1 (20%)	0.749
Hypertension no. (%)	8 (100&)	0 (0%)	0.203
Dyslipidemia no. (%)	3 (100%)	0 (0%)	0.756
Paraparesis or paraplegia	2 (100%)	0 (0%)	0.977
Hemiparesis or hemiplegia	1 (100%)	0 (0%)	0.542
Tumor or cancer	1 (50%)	1 (50%)	0.977
Chronic renal failure	1 (100%)	0 (0%)	0.542
Flap revision			<0.001*
Yes (22 / 58, 37.9%)	9 / 21 (40.9%)	12 / 21 (59.1%)	
No (36 / 58, 62.1%)	35 / 37 (94.4%)	2 / 37 (5.6%)	

Abbreviation: ASA = American Society of Anesthesiologists

TABLE 4. Data comparisons between the group that had surgery from 2000-2014 versus 2015-2019.

Comparative data	Year 2000-2014	Year 2015-2019	p-value
Total cases	30 cases	28 cases	0.165
Flap success no (%)	20 / 30 (66.7%)	24 / 28 (85.7%)	
Flap failure no (%)	10 / 30 (33.3%)	4 /28 (14.3%)	
Flap revision no (%)	12 / 30 (40%)	10 / 28 (35.71%)	0.948
Arterial insufficiency no. (%)	6 / 12 (50%)	4 / 10 (40%)	
Venous congestion no. (%)	6 / 12 (50%)	5 / 10 (50%)	
Bleeding hematoma	0 / 12 (0%)	1 / 10 (10%)	
Flap salvage no (%)	2 / 12 (16.7%)	7 / 10 (70%)	0.036*

What is already known on this topic?

Based on the previous studies, the overall failure rate of microvascular free-flap reconstruction was 5 to 10%. Factors involved in free-flap failure and complications are still debated. Reported factors that relate to flap-failure include the patients' pre-operative status, age, smoking, pre-operative radiation, flap type, surgical expertise, use of vein graft, operative time, and re-exploration for anastomosis revision, but we still did not have sufficient prospective data to definitively identify all the significant causes.

What this study adds

Our institution has operated the microvascular free flap for lower-extremity reconstruction since 1992, but we had not previously collected data or had any long-term outcomes. This retrospective review presents our 20 years of clinical experience with 58 microvascular free-flap reconstruction from various kinds of indication. Our study is not only the first-ever data report from our institute, but may also be the first and largest report of lower-extremity free-flap reconstruction in Thailand.

Potential conflicts of interest

The author declares that there are no conflicts of interest related to this study.

REFERENCES

1. Irons GB, Wood MB, Schmitt EH. Experience with one hundred consecutive free flaps. Ann Plast Surg 1987;18:17-23.
2. Harashina T. Analysis of 200 free flaps. Br J Plast Surg 1988;41:33-6.
3. Percival NJ, Sykes PJ, Earley MJ. Free flap surgery: the Welsh Regional Unit experience. Br J Plast Surg 1989;42:435-40.
4. Schusterman MA, Miller MJ, Reece GP, Kroll SS, Marchi M, Goepfert H. A Single Center' s Experience with 308 Free Flaps for Repair of Head and Neck Cancer Defects. Plast Reconstr Surg 1994;93:472-80.
5. Kruavit A, Visuthikosol V, Srimuninnimit V, Punyahotra N. 10-Year-Free Flaps at Ramathibodi Hospital. Journal of the International College of Surgeons of Thailand. 1998;41:45–59.
6. Kelly JL, Eadie P a, Orr D, Al-Rawi M, O'Donnell M, Lawlor D. Prospective evaluation of outcome measures in free-flap surgery. J Reconstr Microsurg 2004;20:435-8; discussion 439.
7. Classen D a, Ward H. Complications in a consecutive series of 250 free flap operations. Ann Plast Surg 2006;56:557-61.
8. Shpitzer T, Neligan PC, Gullane PJ, Freeman JE, Boyd BJ, Rotstein LE, et al. Oromandibular Reconstruction With the Fibular Free Flap. Arch Otolaryngol Head Neck Surg 1997;123:46-55.
9. Urken ML, Buchbinder D, Costantino PD, Sinha U, Okay D, Lawson W, et al. Oromandibular Reconstruction Using Microvascular Composite Flaps. Arch Otolaryngol Head Neck Surg 1998;124:46-55.
10. Hamdi M, Weiler-Mithoff EM, Webster MH. Deep inferior epigastric perforator flap in breast reconstruction: experience with the first 50 flaps. Plast Reconstr Surg 1999;103:86-95.
11. Cordeiro PG, Disa JJ, Hidalgo D a, Hu QY. Reconstruction of the mandible with osseous free flaps: a 10year experience with 150 consecutive patients. Plast Reconstr Surg 1999;104:1314-20.
12. Nakatsuka T, Harii K, Asato H, Takushima A, Ebihara S, Kimata Y, et al. Analytic review of 2372 free flap transfers for head and neck reconstruction following cancer resection. J Reconstr Microsurg 2003;19:363-8.
13. Suh JD, Sercarz J a, Abemayor E, Calcaterra TC, Rawnsley JD, Alam D, et al. Analysis of outcome and complications in 400 cases of microvascular head and neck reconstruction. Arch Otolaryngol Head Neck Surg 2004;130:962-6.

14. Eckardt a, Meyer a, Laas U, Hausamen J-E. Reconstruction of defects in the head and neck with free flaps: 20 years experience. Br J Oral Maxillofac Surg 2007;45:11–5.
15. Pohlenz P, Blessmann M, Blake F, Li L, Schmelzle R, Heiland M. Outcome and complications of 540 microvascular free flaps: the Hamburg experience. Clin Oral Investig 2007;11:89-92.
16. Wettstein R, Schürch R, Banic A, Erni D, Harder Y. Review of 197 consecutive free flap reconstructions in the lower extremity. J Plast Reconstr Aesthet Surg 2008;61:772-6.
17. Acosta R, Smit JM, Audolfsson T, Darcy CM, Enajat M, Kildal M, et al. A clinical review of 9 years of free perforator flap breast reconstructions: an analysis of 675 flaps and the influence of new techniques on clinical practice. J Reconstr Microsurg 2011;27:91-8.
18. Hallock GG. A paradigm shift in flap selection protocols for zones of the lower extremity using perforator flaps. J Reconstr Microsurg 2013;29:233-40.
19. Hong JP, Shin HW, Kim JJ, Wei F-C, Chung YK. The use of anterolateral thigh perforator flaps in chronic osteomyelitis of the lower extremity. Plast Reconstr Surg 2005;115:142-7.
20. Rodriguez ED, Bluebond-Langner R, Copeland C, Grim TN, Singh NK, Scalea T. Functional outcomes of posttraumatic lower limb salvage: A pilot study of anterolateral thigh perforator flaps versus muscle flaps. J Trauma 2009;66:1311-4.
21. Wei FC, Jain V, Celik N, Chen HC, Chuang DC, Lin CH. Have we found an ideal soft-tissue flap? An experience with 672 anterolateral thigh flaps. Plast Reconstr Surg 2002; 109:2219-26.
22. Chubb D, Rozen WM, Whitaker IS, Acosta R, Grinsell D, Ashton MW. The efficacy of clinical assessment in the postoperative monitoring of free flaps: a review of 1140 consecutive cases. Plast Reconstr Surg 2010;125:1157-66.
23. Rozen WM, Chubb D, Whitaker IS, Acosta R. The efficacy of postoperative monitoring: a single surgeon comparison of clinical monitoring and the implantable Doppler probe in 547 consecutive free flaps. Microsurgery 2010;30:105-10.
24. Chen KT, Mardini S, Chuang DC, Lin CH, Cheng MH, Lin YT, et al. Timing of presentation of the first signs of vascular compromise dictates the salvage outcome of free flap transfers. Plast Reconstr Surg 2007;120:187-95.
25. Khouri RK, Cooley BC, Kunselman AR, Landis JR, Yeramian P, Ingram D, et al. A prospective study of microvascular free-flap surgery and outcome. Plast Reconstr Surg 1998;102:711-21.
26. Kruse AL, Luebbers HT, Gratz KW, Obwegeser JA. Factors influencing survival of free-flap in reconstruction for cancer of the head and neck: a literature review. Microsurgery 2010;30:242-8.
27. Pattani KM, Byrne P, Boahene K, Richmon J. What makes a good flap go bad? A critical analysis of the literature of intraoperative factors related to free flap failure. Laryngoscope 2010;120:717-23.
28. Bourget A, Chang JT, Wu DB, Chang CJ, Wei FC. Free flap reconstruction in the head and neck region following radiotherapy: a cohort study identifying negative outcome predictors. Plast Reconstr Surg 2011;127:1901-8.
29. Herold C, Gohritz A, Meyer-Marcotty M, Steiert A, Jokuszies A, Vaske B, et al. Is there an association between comorbidities and the outcome of microvascular free tissue transfer? J Reconstr Microsurg 2011;27:127-32.