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Outcomes and Risk Factors in Microsurgical Forefoot Reconstruction

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Abstract

Background Defects at the forefoot frequently require microsurgical reconstruction; however, reconstructive failure can lead to results inferior to primary amputation. The purpose of this study was to identify independent factors affecting surgical outcomes and hospitalization time in these patients.

Methods All patients that underwent free flap reconstruction of the forefoot between 2008 and 2019 were reviewed retrospectively. Statistical evaluation included binary logistic regression and correlation analysis.

Results A total of 93 free flap procedures were performed in 87 patients. The most common defect etiologies were acute trauma (30 cases; 32.3%), diabetic foot syndrome (20 cases; 21.5%), and infection (17 cases; 18.3%). Muscle flaps were used in 50 cases (53.8%) and fasciocutaneous flaps were used in 43 cases (46.2%). Major complications occurred in 24 cases (25.8%) including 11 total flap losses and 2 partial flap losses. Minor complications occurred in 38 cases (40.9%). Patients aged 60 years or above were at significant higher risk of major complications ($p = 0.029$). Use of fasciocutaneous flaps (odds ratio [OR]: 14.341; $p = 0.005$), arterial hypertension (OR: 18.801; $p = 0.014$), and operative time (min) (OR: 1.010; $p = 0.029$) were identified as individual risk factors for major complications. Two venous anastomoses significantly reduced the risk of major complications (OR: 0.078; $p = 0.022$). Multiresistant bacterial wound colonization (OR: 65.152; $p < 0.001$) and defect size (OR: 1.007; $p = 0.045$) were identified as independent risk factors for minor complications. The median hospital stay was 28 days (7–85 days). Age significantly correlated with the length of hospital stay ($r = 0.405$, $p < 0.01$).

Conclusion Our study identified independent risk factors that might help to make individual decisions whether to target microsurgical forefoot reconstruction or primary amputation. Two venous anastomoses should be performed whenever feasible, and muscle free flaps should be preferred in patients at higher risk of major surgical complications.

Keywords
- microsurgical forefoot reconstruction
- free flap
- risk factors
- comorbidities
- complications

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Due to the complex anatomical situation as well as spare soft tissue coverage of the forefoot, even defects of relatively small size commonly are a reconstructive challenge. Forefoot defects often are complex to reconstruct due to exposed tendons or bones, making them a possibly limb-threatening condition when treated insufficiently. In addition, form and function of the forefoot require a thin but yet durable soft tissue coverage sustaining weight-bearing and sheering forces. Hence, the forefoot is an example for the concept of the reconstructive elevator[1] as it is an area where microsurgical reconstruction is the method of choice in many cases.

The etiology of forefoot defects can be categorized in traumatic and ischemic defects. While both etiologies might result into similar defects, the patient characteristics, patient expectations, local factors, and outcome prognosis vary highly for both groups.[2] For the trauma population, previous studies failed to show functional long-term benefits with limb salvage,[3,4] whereas in the nontraumatic population, amputation is associated with a high risk of immobility.[5,6] The level of amputation is directly associated with the functional outcome[7] and survival.[8] Thus, even situations where parts of the distal lower extremity are not salvageable do not exclude the need for microsurgical reconstruction with free flap transfers, as it might enable functional amputations to avoid below knee amputation.

The final decision in favor of a major amputation or reconstruction cannot be made based on published severity scores but is always an individual decision.[9] The aim of this study was to identify independent preoperative and intraoperative factors affecting surgical complication rates and hospitalization time in microsurgical forefoot reconstruction.

Methods

A retrospective analysis of all patients that underwent free flap reconstruction of the forefoot at our institution between 2008 and 2019 was performed. The forefoot was defined as the area distal from the tarsometatarsal joints (Lisfranc joints). Wounds extending the main defect at the forefoot proximally beyond the Lisfranc joints were also included. Medical records were reviewed for patient demographics (age, American Society of Anesthesiologists [ASA] physical status classification, comorbidities (arterial hypertension, diabetes (including preoperative glycated hemoglobin [HbA1c] levels), hyperlipidemia, peripheral arterial disease, coronary heart disease, renal insufficiency (defined as serum creatinine levels >1.28 mg dL [−1]), risk factors (smoking, multiresistant bacterial wound contamination, osteomyelitis), defect characteristics (etiology, location, area), intraoperative details (flap type, recipient vessels, number of venous anastomoses, type of anastomoses, pedicle length, ischemia time, total operative time), and length of hospital stay.

Peri- and Postoperative Standard of Care

Prereconstruction workup includes angiologic screening in patients suspected of peripheral arterial disease with subsequent intervention in case of critical ischemia and radical debridement of infected and avital tissue prior free flap coverage. Perioperative prophylactic anticoagulation is provided for all patients except for those with indications for special anticoagulation regimens due to comorbidities. Provided an uneventful postoperative course, dangling protocol starts on the fifth postoperative day with 5-minute periods during every hour awake under moderate compression wrapping and clinical monitoring. The dangling period is subsequently increased by 5 minutes every day. In case of signs of venous flap congestion during the dangling period, the duration of the period is reduced. Provided stable wound situations and complete skin graft take, ambulation is initiated 2 weeks after flap coverage under continuous compression garment therapy and with a forefoot offloading shoe in cases with plantar defects.

Surgical Outcome Measures

Major complications included total or partial flap loss of more than 10% of flap tissue, flap thrombosis requiring subsequent revision, and hematoma requiring surgical evacuation. Minor complications included partial flap loss of less than 10% of flap tissue, skin graft failure in case of muscle flaps, and wound dehiscence.

Statistical Analysis

To determine independent risk factors for minor or major complications in free flap transfer, a binary logistic regression analysis was performed for all preoperative and intraoperative variables. To assess linear association between two quantitative parameters, Pearson (parametric) or Spearman (nonparametric) correlation coefficient was calculated. A *p*-value less than 0.05 was considered statistically significant. Analyses were performed using IBM SPSS Statistics Version 26.0.

The study protocol was approved by the institutional ethical review committee and written informed consent was obtained from all patients.

Results

Patient and Flap Characteristics

The chart review identified a total of 93 free flap procedures in 87 patients, of whom 6 patients received 2 flaps for 1 defect. Eighteen patients (20.7%) were female and 69 (79.3%) were male. The mean age at the time of surgery was 55 (7–88) years. The ASA classification status was class I for 18 patients (20.7%), class II for 36 patients (41.4%), class III for 32 patients (36.8%), and class IV for 1 patient (1.1%). Among the most common medical comorbidities was arterial hypertension in 45 patients (51.7%) followed by diabetes in 35 patients (40.2%) (►**Table 1**). The patients with diabetes had a mean hemoglobin A1c (HbA1c) level of 9.2% (6.1–14.4), based on preoperative blood testing. Among the 15 patients with peripheral arterial disease, in 6 patients preoperative duplex sonography showed critical perfusion. These patients underwent percutaneous transluminal angioplasty prior to free flap reconstruction.

Table 1 Medical comorbidities and risk factors

	All patients ($n = 87$)	Nondiabetic ($n = 52$)	Diabetic ($n = 35$)	p-Value
Arterial hypertension	45 (48.4%)	19 (36.5%)	26 (74.3%)	<0.001
Diabetes	35 (37.6%)	n/a	35 (100%)	n/a
Hyperlipidemia	21 (22.6%)	9 (17.3%)	12 (34.3%)	0.044
Peripheral arterial disease	15 (16.1%)	4 (7.7%)	11 (31.4%)	0.003
Coronary heart disease	12 (12.9%)	1 (1.9%)	11 (31.4%)	<0.001
Smoking	22 (23.7%)	17 (32.7%)	5 (14.3%)	0.132
Osteomyelitis	14 (15.1%)	3 (5.8%)	11 (31.4%)	0.002
Multiresistant bacterial wound colonization	12 (12.9%)	5 (9.6%)	7 (20.0%)	0.125

Abbreviation: n/a, not available.

Table 2 Distribution of defect localizations (one localization assigned per each forefoot indicating the main defect)

	Number of cases ($n = 93$)
Dorsal	44 (47.3%)
Medial	18 (19.4%)
Plantar	18 (19.4%)
Lateral	7 (7.5%)
Distal	6 (6.5%)

The mean defect area measured 105 (4–450) cm^2. Most of the defects were located at the dorsum of the foot (►**Table 2**). The most common defect etiology was acute trauma with 30 cases (32.3%), followed by diabetic foot syndrome with 20 cases (21.5%) and infection with 17 cases (18.3%). Other etiologies were burn wounds (12 cases, 12.9%), postoperative wound healing disorder (10 cases, 10.8%), tumors (2 cases, 2.2%), scars (1 cases, 1.1%), and foot deformity (1 case, 1.1%). Muscle flaps were used in 50 cases (53.8%) and fasciocutaneous flaps were used in 43 cases (46.2%) (►**Table 3**). In 70 flaps (75.3%), arterial anastomosis was performed end-to-end and in 23 flaps (24.7%) arterial anastomosis was done end-to-side. In 35 flaps (37.6%) one venous anastomosis and in 58 flaps (62.4%) two venous anastomosis were performed.

Table 3 Flap type overview

	Number of cases ($n = 93$)
Gracilis muscle flap	39 (41.9%)
ALT flap	32 (34.4%)
Latissimus dorsi muscle flap	9 (9.7%)
Superficial circumflex iliac artery perforator flap	9 (9.7%)
Parascapular flap	2 (2.2%)
Rectus femoris muscle flap	1 (1.1%)
Serratus muscle flap	1 (1.1%)

Abbreviation: ALT, anterolateral thigh.

The mean follow-up period for all patients was 85 (14–152) months.

Surgical Complications

Major complications occurred in 24 cases (25.8%) including 11 total flap losses and 2 partial flap losses. Minor complications occurred in 38 cases (40.9%) (►**Table 4**). Revision surgery was necessary in 48 cases (51.6%) with 10 local flaps, 22 skin grafts, 9 combined local flaps and skin grafts, and 5 secondary sutures. In 2 patients (2.3%), failed flap reconstruction resulted in below knee amputation.

Subtype Analysis of Diabetic Patient Population

All diabetic patients were male and significantly older than nondiabetic patients, with a mean age of 57 and 44 years, respectively ($p < 0.001$). ASA status was significantly higher in diabetic patients (<0.001). The diabetic patient population had significantly higher rates of medical comorbidities and risk factors: arterial hypertension (74.3 vs. 36.5%; $p < 0.001$), hyperlipidemia (34.3 vs. 17.3%; $p < 0.044$), peripheral arterial disease (31.4 vs. 7.7%; $p = 0.003$), coronary heart disease (31.4 vs. 1.9%; $p < 0.001$), and osteomyelitis (31.4 vs. 5.8%; $p = 0.002$). The mean defect area did not differ between diabetic and nondiabetic patients (103.8 vs. 107.5 cm^2; $p = 0.624$; ►**Table 1**).

There was no significant difference in complication rates between diabetic and nondiabetic patients: minor complications (42.9 vs. 39.7%; $p = 0.829$), major complications (28.6 vs. 24.1%; $p = 0.634$), and total flap loss (8.6 vs. 13.8%; $p = 0.53$; ►**Table 4**). Preoperative HbA1c levels showed no correlation with minor complications ($p = 0.450$) or major complications ($p = 0.302$) in diabetic patients.

Risk Factor Analysis

Univariate regression analysis showed significantly increased risk (odds ratio [OR]: 2.895; 95% confidence interval [CI]: 1.112–7.537; $p = 0{,}029$) for major complications in patients aged 60 years or above, while multivariate regression analysis demonstrated that age was not an individual risk factor for complications. Based on multivariate regression analysis patients that received fasciocutaneous flaps and patients with arterial hypertension had significant

Table 4 Complication overview

	Number of cases ($n=93$)	Nondiabetic ($n=58$)	Diabetic ($n=35$)	p-Value
Major complication	**24 (25.8%)**	**14 (24.1%)**	**10 (28.6%)**	**0.634**
Total flap loss	11 (11.8%)	8 (13.8%)	3 (8.6%)	0.526
Partial flap loss >10%	2 (2.2%)	1 (1.7%)	1 (2.9%)	
Thrombosis	15 (16.1%)	12 (20.7%)	3 (8.6%)	
Hematoma	5 (5.4%)	1 (1.7%)	4 (11.4%)	
Thrombosis and hematoma	2 (2.2%)	0 (0.0%)	2 (5.7%)	
Minor complication	**38 (40.9%)**	**23 (39.7%)**	**15 (42.9%)**	**0.829**
Partial flap loss <10%	7 (7.5%)	6 (10.3%)	1 (2.9%)	
Wound dehiscence	23 (24.7%)	13 (22.4%)	10 (28.6%)	
Skin graft failure	8 (8.6%)	4 (6.9%)	4 (11.4%)	
Revision surgery	**54 (58%)**	**32 (55.2%)**	**22 (62.9%)**	**0.520**
Below knee amputation	**2 (2.2%)**	**1 (1.7%)**	**1 (2.9%)**	**1.000**

higher odds for major complications (OR: 14.341; $p=0.005$ and OR: 18.801; $p=0.014$). Length of surgery was also significantly related to major complications, increasing the risk relatively by 1% per minute operative time (OR: 1.010; $p=0.029$). Two venous anastomoses significantly reduced the risk of major complications (OR: 0.078; $p=0.022$; ►**Table 5**). Multiresistant bacterial wound colonization was strongly associated with minor complications (OR: 65.152; $p<0.001$). Defect size was also significantly associated with minor complications (OR: 1.007; $p=0.045$), while smoking trended toward association with minor complications (OR: 4.574; $p=0.069$; ►**Table 6**). ASA classification, diabetes, hyperlipidemia, peripheral arterial disease, coronary heart disease, renal insufficiency, defect etiology, defect location, osteomyelitis, recipient vessel, type of arterial anastomosis, pedicel length, and ischemia time were not identified as risk factors by the multivariate model.

Length of Hospital Stay

The median hospital stay was 28 days (7–85 days) for all patients. Age significantly correlated with the length of hospital stay ($r=0.405$, $p<0.01$), while ASA classification showed no correlation.

Table 5 Individual risk factors for major complications in microsurgical forefoot reconstruction

	OR	95% CI	p-Value
Fasciocutaneous flaps	14.341	2.191–93.849	0.005
Arterial hypertension	18.801	1.803–196.084	0.014
Two venous anastomoses	0.078	0.009–0.694	0.022
Length of surgery (min)	1.010	1.001–1.019	0.029

Abbreviations: CI, confidence interval; OR, odds ratio.

Discussion

Both in the trauma and in the diabetic or ischemic patient population, sufficient reconstruction of the forefoot frequently requires microsurgical free flap transfer. In the diabetic population, successful limb salvage and prevention of major lower extremity amputation significantly influence mortality[10] thus, forefoot reconstruction holds a special role in these patients. However, if microsurgical reconstruction fails, the amputation level might even go more proximal than with primary amputation.[11] Furthermore, delayed amputation results in prolonged hospitalization, higher number of surgeries, higher mortality, and higher costs.[2] This is particularly relevant as success rates for microsurgical lower extremity reconstruction are significantly lower compared to other sites in the body.[12] Studies focusing on free flap reconstruction of the foot for varying defect etiologies reported flap survival rates ranging from 73 to 100%.[13–19] In our series, flap survival rate reached 86%, and therefore it is comparable to previously published data but markedly lower than our institution's general flap survival rate of 94.9%.[20]

There is still lacking evidence on independent factors influencing the outcome in free flap transfer to the forefoot. Only three studies limited to diabetic foot defects investigated possible risk factors for postoperative complications.[21–23] Oh et al[21] investigated 121 cases of microsurgical diabetic

Table 6 Individual risk factors for minor complications in microsurgical forefoot reconstruction

	OR	95% CI	p-Value
Multiresistant bacteria	65.152	5.563–763.047	<0.001
Defect size (cm^2)	1.007	1.000–1.015	0.045
Smoking	4.574	0.887–23.580	0.069

Abbreviations: CI, confidence interval; OR, odds ratio.

foot reconstruction and identified peripheral arterial disease, a history of angioplasties in the lower extremity and using immunosuppressive agents after kidney transplantation to increase the chance for flap loss, while ASA status showed no effect on flap survival. In contrast, Kim et al[22] found both impaired arterial status of the heel and ASA status to significantly increase the risk of flap failure in 37 patients with diabetic heel defects. Lee et al[23] analyzed 33 patients with free flap reconstruction for diabetic feet defects and found atherosclerotic calcifications and serum creatinine levels more than 1.28 mg dL (-1) to significantly affect the complication rate. In our study, none of the factors identified in the previously mentioned diabetic case series served as an independent risk factor. Synergistic effects of these factors together with diabetes might explain the discrepancy between our findings and published data for diabetic foot defects. However, in our study population only one patient was classified with ASA status IV and only six patients had moderately elevated preoperative serum creatine levels (maximum 1.9 mg dL$[-1]$), limiting the strength of our study concerning these two factors.

In our study, population diabetes was represented in both as a leading etiologic factor in 20 cases and as cofounding risk factor in defects other than diabetic origin in further 15 cases. Diabetes was, therefore, not found to be an independent risk factor for complications in our study. This is in agreement with Kantar et al[24] that evaluated the effect of diabetes in a cohort of 6,030 free flaps not limited to an anatomical site and found no association with free flap failure, while the existing literature on microsurgical lower extremity reconstruction is indecisive regarding the role of diabetes.[25,26] Subgroup analysis further showed that preoperative HbA1c levels did not correlate with complication rates in the diabetic patient population. While patients aged 60 years or above had significant higher risk of major complications, chronological age was not identified as an independent risk factor in our series. This is in agreement with the role of age in microsurgical procedures in general.[27,28]

We found a strong association of arterial hypertension with major complications. This could possibly be explained by the fact that arterial hypertension is related to a hypercoagulable state[29] and experimental data also suggests potential disadvantageous effects of antihypertensive drugs on flap survival.[30] In the study of Las et al[25] reviewing possible risk factors in 330 microsurgical lower extremity reconstructions arterial hypertension trended towards significancy in univariate analysis, while no significance was shown in multivariate analysis. Other previous studies focusing on microsurgical extremity reconstruction could not find an association of hypertension with flap failure[22,26,31] or did not include arterial hypertension in their risk factor analysis.[23,32,33]

Each minute operative time significantly increased the risk of major complications. This was previously reported by several studies[25,32,34,35] and is most likely attributed to intraoperative difficulties that influence both operative time and final flap outcome.

Our results suggest a protective effect of performing two venous anastomoses. The impact of the number of venous anastomoses on flap success rate is an ongoing controversy in microsurgical literature. Both experimental and various clinical studies investigated the effect of single or dual venous drainage, however, with conflicting results.[36–39] The anatomic location and inactivated skeletal muscle pump due to immobilization predispose the forefoot to insufficient venous return and venous stasis[40] and might have potentiated the positive effects of a second venous drainage in our study group.

Flap choice was another significant non patient related factor influencing surgical outcomes. We found a four times higher risk of major complications with fasciocutaneous flaps. Several previous studies reported equal outcomes for fasciocutaneous and muscle free flaps but were limited to posttraumatic reconstructions and did not exclusively investigate foot defects.[41–43] Lee et al[44] reviewing 165 free flap reconstructions of traumatic ankle and foot defects also found no difference regarding flap survival among both flap groups. Based on our results, we recommend the use of muscle flaps for patients at higher risk of major complications. As this typically applies to the older aged patients with ischemic defects, there is usually no need for flap reelevation due to secondary orthopaedic procedures. Furthermore, muscle flaps are ideal to obliterate deep dead spaces that commonly remain after radical debridement of ischemic foot defects. The gracilis muscle flap is our workhorse flap in these patients as its harvest does not impede with subsequent remobilization,[45] its size is sufficient for most ischemic foot defects[46,47] and decrease of flap volume due to atrophy allows anatomical surface reconstruction (►**Fig. 1A–D**).

The median hospital stay of 28 days in our study appears relatively long but is similar to previous published data on microsurgical extremity reconstructions.[48,49] Higher age was related to longer hospitalization time, which demonstrates that (major) complications, besides their possible effect on the final outcome, also have a markedly impact on hospitalization time with all its consequences such as prolonged immobilization, delayed rehabilitation and higher costs.

The presented study has several limitations inherent to a retrospective review. Further, it is also limited by the fact that it is not a single-surgeon study.

Conclusion

When it comes to complex forefoot defects, the reconstructive surgeon has to deal with the dilemma, that older patients who benefit the most from microsurgical limb salvage at the same time have the highest risk of surgical complications and prolonged hospital stays. Our study identified independent risk factors for surgical complications. Precisely, arterial hypertension, use of fasciocutaneous flaps, and total operative time were associated with major complications, while performing two venous anastomoses resulted in significantly fewer major complications. Multiresistant bacterial

Fig. 1 (**A**) A 69-year-old woman with American Society of Anesthesiologists III classification presented with a soft tissue defect of the dorsum of the right forefoot measuring 8 × 5 cm with exposure of extensor tendons and the first and second metatarsal bones after phlegmon and subsequent surgical debridement. (**B**) The defect was covered with a skin grafted free gracilis flap harvested from the contralateral thigh and anastomosed end-to-end to the dorsalis pedis artery and accompanying vein. The postoperative course was uneventful and the patient was discharged 7 days after the free flap procedure. (**C** and **D**) Eleven years follow-up showed a stable coverage with an anatomical surface reconstruction and a relatively inconspicuous scar pattern.

wound colonization and defect size were associated with minor complications. Furthermore, higher age showed significant association with longer hospitalization time. Our results might help in future patient counseling and decision making in favor of microsurgical forefoot reconstruction or primary amputation.

Conflict of Interest
None declared.

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