Journal of Plastic, Reconstructive & Aesthetic Surgery (2021) 74, 512–522

JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

Predicting risk factors that lead to free flap failure and vascular compromise: A single unit experience with 565 free tissue transfers

Ioana Lese*, Raphael Biedermann, Mihai Constantinescu, Adriaan O. Grobbelaar, Radu Olariu

Department of Plastic and Hand Surgery, Inselspital, Bern University Hospital, Freiburgstrasse 4, 3010 Bern, Switzerland

Received 7 March 2020; accepted 25 August 2020

KEYWORDS
Free flap;
Predictability;
Index;
Complications;
Flap failure

Summary *Background:* Even though the benefit of free tissue transfer is uncontested in complex reconstructive cases, vascular compromise and/or flap failure remain a challenge for the surgeon and identification of possible risk factors can aid in the preoperative planning. The aim of this study was to identify the individual risk factors leading to flap failure and/or vascular compromise in free tissue transfers in a single institution over a period of 10 years and to create an index predicting these problems, as well as finding predictors of other postoperative complications.
Methods: Data from all the patients undergoing free tissue transfers between 2009 and 2018 were retrospectively analyzed (demographics, comorbidities, flap failure, vascular compromise, and other complications). The results from the univariate and multivariate analyses were used to create an index.
Results: A predictability index with three classes (low, moderate, and high risk) was calculated for each patient, based on defect etiology and the presence of coronary heart disease, diabetes, smoking, peripheral arterial vascular disease, and arterial hypertension. A patient with moderate-risk index had 9.3 times higher chances of developing vascular compromise than those in the low-risk group, while a high-risk index had 18.6 higher odds (p=0.001). American Society of Anesthesiologists (ASA) classification was found to be a predictor of complications in free tissue transfer (p=0.001).

* Corresponding author.
E-mail address: ioana.lese@gmail.com (I. Lese).

https://doi.org/10.1016/j.bjps.2020.08.126

Conclusion: If patients at a high risk of vascular compromise could be identified preoperatively through this predictability index, patient counseling could be improved and the surgeon might adapt the reconstructive plan and choose an alternative reconstructive strategy.

Introduction

Since 1972, when McLean and Buncke reported the first free tissue transfer, a multitude of free flaps have been envisioned and described.[1] Free flaps are normally reserved for the most complex reconstructions and are often the only option left to the reconstructive surgeon.[2] Therefore, a better understanding of the risk factors associated with flap failure and return to theater with vascular compromise requiring anastomotic revision could potentially aid the surgeons to tailor their decision-making process and provide patients with improved counseling before consenting to such complex procedures. It could also potentially lead to a different surgical strategy taking into consideration individual patientś surgical and medical history.

Even though great effort has been made in refining the microsurgical techniques and reducing the operator-dependent technical errors, the postoperative complications are still high.[3,4] Nevertheless, patients' characteristics also seem to play an important role in the outcomes of free flaps.[5-7] Usually, reports are based on specific anatomical areas, for example, head and neck,[8,9] lower extremity[10,11] or breast reconstruction.[12] Therefore, it is not clear whether these previously identified risk factors for different regions have the same effect across the entire microsurgical reconstructive spectrum.

The primary aim of this study is to identify the individual risk factors leading to flap failure and re-exploration of the microsurgical anastomosis in free tissue transfers in a single institution over a period of 10 years and to create an index predicting these problems. Secondly, the study also examines predictors of other postoperative complications.

Patients and methods

All patients undergoing free tissue transfer between 2009 and 2018 in the Department of Plastic and Reconstructive surgery, University Hospital in Bern, Switzerland, were considered for this study. The following patient-related data were retrospectively collected for each patient: age at time of surgery, gender, American Society of Anesthesiologists (ASA) classification, alcohol and tobacco consumption, obesity, medical comorbidities (high blood pressure, diabetes mellitus, heart failure, coronary artery disease, and others), defect etiology, defect location, and flap used. Each free flap performed was considered as a single encounter; thus, patients who received multiple free flaps at once were considered as multiple encounters, as well as free flaps performed on the same patient but at different time points.

Flap failures, as well as vascular compromise necessitating return to theater, and all complications were recorded. In order to create an index predicting flap failure and/or vascular compromise, we analyzed surgical etiology, as well as comorbidities using the Mann-Whitney U test for the continuous variables, while Pearson's χ^2 test and Fischer's exact test were conducted for the categorical variables. Depending on the results, the presence of various conditions was scored in order to create an index with low, moderate and high risk for vascular compromise, return to theater, and flap failure.

The postoperative surgical complications (infection, partial flap necrosis, postoperative bleeding, hematoma, seroma, dehiscence, and others) were divided into minor and major complications as follows: minor complications were considered conditions that were treated conservatively, without returning to the operating theater, while major complications were the ones that required surgical reintervention. In order to analyze the complications, factors with a significance of $p < 0.2$ in the univariate analysis were included in the multivariate binominal logistic regression model to identify independent risk factors for postoperative complications. Statistical analysis was performed using SPSS 23.0 (SPSS Inc., Chicago, USA).

The study was conducted according to the Declaration of Helsinki principles and was approved by the local Research Ethics Committees (ID 2018-00312).

Results

From 2009 to 2018, 580 free flap procedures were identified, with 15 of them having missing data. Therefore, only 565 free flaps were included in this study. Patients' demographic and clinical characteristics are outlined in Table 1. The distribution of defect etiology, defect location and type of flap used for reconstruction are illustrated in Figures 1–3, respectively.

Flap failures and return to theater

There were 35 patients with vascular compromise, 14 arterial and 21 venous. In the arterial group, 10 flaps were taken back on the first postoperative day, but only 1 was saved. Both of the flaps with arterial occlusion on the second postoperative day, one flap on the third postoperative day and one flap on the forth postoperative day were lost despite revision. Therefore, we recorded a 7.1 % salvage rate among the flaps with arterial occlusion (1 out of 14). Vein occlusion occurred in 21 flaps and had a salvage rate of 85.71

Table 1 Patients' demographic and clinical characteristics.

Characteristics	Category	Number (%) or Median [Range]
Patient's age		52.83 [6-93]
Gender		
	Women	217 (38.4%)
	Men	348 (61.6%)
ASA		
	1	141 (25)
	2	275 (48.7)
	3	139 (24.6)
	4	10 (1.8)
Alcohol		
	No	460 (81.4)
	Yes	105 (18.6)
Smoking		
	No	382 (67.6)
	Yes	183 (32.4)
Obesity		
	No	481 (85.1)
	Yes	84 (14.9)
High Blood Pressure		
	No	415 (73.5)
	Yes	150 (26.5)
Diabetes mellitus		
	No	515 (91.2)
	Yes	50 (8.8)
Heart Failure		
	No	541 (95.8)
	Yes	24 (4.2)
Coronary Heart Disease		
	No	524 (92.7)
	Yes	41 (7.3)
Cerebrovascular Accident		
	No	561 (99.3)
	Yes	4 (0.7)
Peripheral Arterial Occlusive Disease		
	No	535 (94.7)
	Yes	30 (5.3)
COPD or Asthma		
	No	512 (90.6)
	Yes	53 (9.4)
Chronic venous insufficiency		
	No	556 (98.4)
	Yes	9 (1.6)
Comorbidity		
	No	283 (50.1)
	Yes	282 (49.9)

% (18 out of 21). Seventeen flaps were revised on the first postoperative day, with success in 15 cases, while the other four were taken back to theater on the second postoperative day, with three of them being saved. When looking exactly at the etiology of vascular compromise that preceded flap failure, the 13 cases due to arterial occlusion proved to be statistically significant (<0.001) when compared to the venous occlusion. In the patients with arterial and venous occlusion, there was no statistically significant difference in terms of comorbidities, gender, or age.

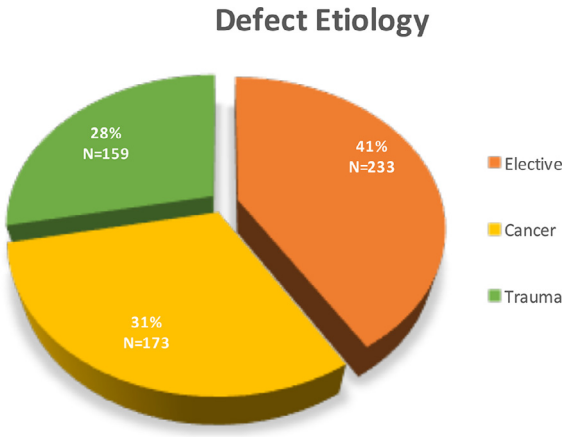

Figure 1 Defect etiology: 1. Elective: free tissue transfer for various cancers that were reconstructed in a delayed fashion more than three months after the initial resection, chronic osteomyelitis with plate infection or other posttraumatic complications ensuing more than 3 months after the initial surgical intervention and osteoradionecrosis; 2. Cancer: patients with various malignancies undergoing free tissue transfer immediately or at a maximum of 3 months after tumor resection; 3. Trauma: patients with soft-tissue trauma and fractures, including infections, undergoing reconstructive surgery immediately or at a maximum of 3 months after the incident.

Table 2 summarizes the characteristics of the patients with and without vascular compromise. In order to create an index predicting flap failure and/or vascular compromise, each of the following comorbidities were assigned a score of 1: smoking, the presence of arterial hypertension, diabetes mellitus, coronary heart disease, and peripheral arterial vascular disease. We analyzed the different etiological groups and found a trend in flap failure and/or vascular compromise between the various etiologies ($p<0.2$): in the elective group, there were 3.8% cases with vascular compromise, while the cancer group recorded 6.9% and the trauma group had a vascular compromise rate of 8.9%. A statistical significance was reached when the elective group was compared to the trauma group ($p=0.038$). Based on this analysis, we assigned the following predictability score to each etiological group: elective - 1, cancer - 2 and trauma - 3. This allowed us to create a predictability index ranging from 1 to 8 points calculated for each patient. In order to predict the risk of vascular compromise, we subdivided the predictability index in three groups: low risk (index 1 and 2), moderate risk (index 3, 4, and 5), and high risk (index 6, 7, and 8). Table 3 shows the vascular compromise rate in each group. In the binominal logistic regression analysis, increasing index group was associated with an increased likelihood of exhibiting vascular compromise ($p=0.001$): a patient with a moderate-risk index had 9.3 times higher chances of developing vascular compromise than those in the low-risk group, while a high-risk index had 18.6 higher odds. Therefore, our predictability index appeared to be an accurate predictor of flap failure and/or vascular compromise. However, it is not able to predict flap salvage. These findings were supported to a certain extent by the ASA score, but only when comparing ASA 4 to ASA 1, since the other scores

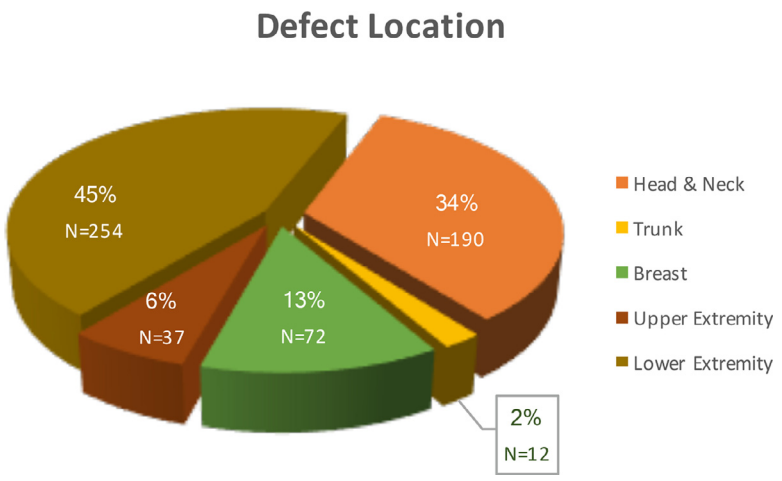

Figure 2 Defect location.

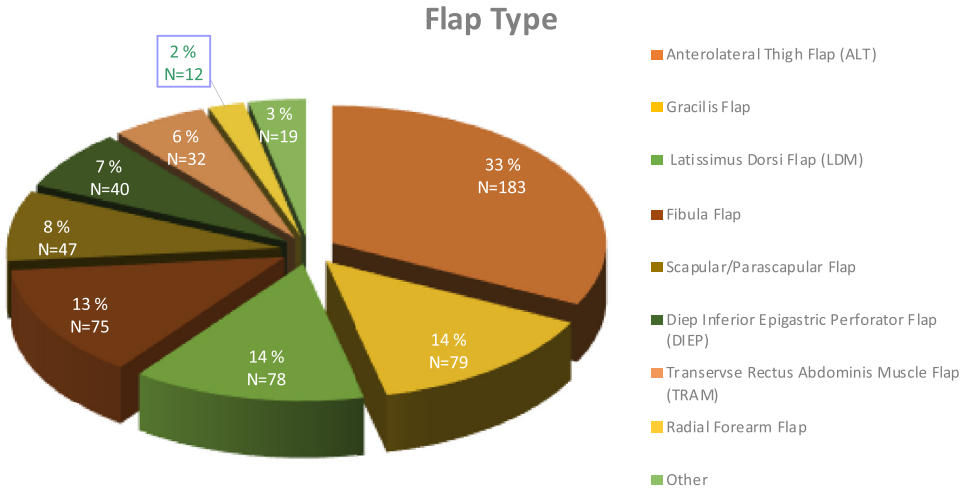

Figure 3 Flap type. *Other flap types include vertical rectus abdominis muscle flap (VRAM), medial plantar artery flap (MPAF), supraclavicular artery perforator flap (SAPF), tensor fascia lata flap (TFL), vastus lateralis muscle flap, rectus femoris muscle flap, groin flap, and serratus flap.

Table 2 Univariate risk factor analysis for flap failure and/or vascular compromise.

Characteristic		No Flap Failure and/or Vascular Compromise	Flap Failure and/or Vascular Compromise	*P* value
Patient's age		51.24 6-93	50.13 17-78	0.715
Gender				0.381
	Female	206 (94.9)	11 (5.1)	
	Male	324 (93.1)	24 (6.9)	
ASA score				0.012
	ASA 1	135 (95.7)	6 (4.3)	
	ASA 2	259 (94.2)	16 (5.8)	
	ASA 3	129 (92.8)	10 (7.2)	
	ASA 4	7 (70)	3 (30)	
Alcohol				0.947

(*continued on next page*)

Table 2 (*continued*)

Characteristic		No Flap Failure and/or Vascular Compromise	Flap Failure and/or Vascular Compromise	*P* value
	No	431 (93.7)	29 (6.3)	
	Yes	99 (94.28)	6 (5.72)	
Smoking				0.004
	No	366 (95.8)	16 (4.2)	
	Yes	164 (89.6)	19 (10.4)	
Obesity				0.378
	No	453 (94.2(	28 (5.8)	
	Yes	77 (91.7)	7 (8.3)	
Arterial Hypertension				0.063
	No	394 (94.9)	21 (5.1)	
	Yes	136 (90.7)	14 (9.3)	
Diabetes mellitus				0.000
	No	494 (95.9)	21 (4.1)	
	Yes	36 (72)	14 (28)	
Heart failure				0.657
	No	508 (93.9)	33 (6.1)	
	Yes	22 (91.7)	2 (8.3)	
Cerebrovascular accident				0.606
	No	526 (93.8)	35 (6.2)	
	Yes	4 (100)	0 (0)	
Coronary heart disease				0.000
	No	501 (95.6)	23 (4.4)	
	Yes	29 (70.7)	12 (29.3)	
Peripheral arterial vascular disease				0.000
	No	509 (95.1)	26 (4.9)	
	Yes	21 (70)	9 (30)	
COPD or Asthma				0.304
	No	482 (94.1)	30 (5.9)	
	Yes	48 (90.6)	5 (9.4)	
Chronic venous insufficiency				0.437
	No	521 (93.7)	35(6.3)	
	Yes	9 (100)	0 (0)	
Defect etiology				0.115
	Elective	225 (96.2)	9 (3.8)	
	Cancer	161 (93.1)	12 (6.9)	
	Trauma	144 (91.1)	14 (8.9)	
Defect Location				0.329
	Head & Neck	178 (93.7)	12 (6.3)	
	Trunk	12 (100)	0 (0)	
	Breast	71 (98.6)	1 (1.4)	
	Upper Extremity	34 (91.9)	3 (8.1)	
	Lower Extremity	235 (92.5)	19 (7.5)	
Flap type				0.555
	ALT	171 (93.4)	12 (6.6)	
	Gracilis	74 (93.7)	5 (6.3)	
	Latissimus dorsi	72 (92.3)	6 (7.7)	
	Fibula	70 (93.3)	5 (6.7)	
	Scap/Parascap	45 (95.7)	2 (4.3)	
	DIEP	39 (97.5)	1 (2.5)	
	TRAM	32 (100)	0 (0)	
	Radialis	11 (91.7)	1 (8.3)	
	Other	16 (84.2)	3 (15.8)	

Table 3 Flap failure and/or vascular compromise predictability index.

Predictability Index	No Flap Failure and/or Vascular Compromise	Flap Failure and/or Vascular Compromise
Low-risk (index 1 & 2)		
Number	251	3
Percentage	98.8 %	1.2 %
Moderate-risk (index 3, 4 & 5)		
Number	270	30
Percentage	90 %	10 %
High-risk (index 6, 7 & 8)		
Number	9	2
Percentage	81.8%	18.2 %

did not reach statistical significance: a patient with ASA 4 has a 9.6 times higher chance of having problems with flap failure and/or vascular compromise than a patient with ASA 1.

Postoperative complications

An overview of the postoperative complications is presented in Table 4. There were 183 flaps (32.4 %) with other postoperative complications, with some patients experiencing only minor or major complications, while others were treated both conservatively and surgically for the postoperative complications. In total, there were 42 minor complications (7.4 %) and 152 major complications (26.9 %).

The results of the univariate and multivariate analysis are summarized in Tables 5 and 6, respectively. The ASA score, along with the presence of diabetes and cerebrovascular accident, showed statistical significance ($p<0.05$). Since the ASA score was overlapping with the various comorbidities, we decided to use the ASA score as the sole comorbidity representative in the logistic regression, as well as the other variables with $p<0.2$. Of all the predictors, only two were statistically significant: the ASA score and flap type. Patients with ASA 2 had 2.2 times higher odds to develop postoperative complications, while ASA 3 increased the chances by 2.6. Patients with ASA 4 had 11.8 times increased chances of postoperative complications in comparison to patients with ASA 1. Moreover, the flap type also had an influence on postoperative complications: patients undergoing free osteo-septo-cutaneous fibula flap recorded a 2.33 times higher chance of developing postoperative complications.

Discussion

Flap failures and return to theater

The advances achieved in microsurgery have given surgeons the armamentarium to deal with some of the most complex defects. Free tissue transfer has achieved widespread popularity and can be considered a safe and reliable method, yielding success rates between 92.3% and 98%.[9,10,13-15] Even though the benefit of free flap reconstruction is uncontested in successful cases, vascular compromise and/or flap failure still remain a challenge for the surgeon, and identification of possible risk factors can aid in the preoperative planning and counseling of the patient. Our index allows the reconstructive surgeon to stratify the risk for vascular compromise and in certain situations, it may aid in adjusting the reconstructive plan. Even though our flap success rate was well within the range of acceptability of reported series (97.2%), we aimed to identify the factors playing a significant role in flap failure and/or vascular compromise in our hands and if possible, produce an index predicting these problems in practice and hopefully then be able to adjust or modify our reconstructive plan in the future.

Most series in the literature looking at flap failure and risk factors is restricted to a specific practice, for example, head and neck or breast reconstruction, while our series deals with the entire spectrum of reconstructive surgery. On the one hand, studies[16,17] looking at head and neck cases found that smoking, diabetes, heart disease and the presence of comorbidities were not risk factors for flap thrombosis in their univariate analysis. The lack of these variables as risk factors was also reported in a breast reconstruction study,[12] although smoking was near the statistical significance limit. On the other hand, in our series covering the entire reconstructive field, the presence of arterial hypertension, diabetes, coronary heart disease, peripheral arterial occlusive disease and smoking, in combination with the etiology of the surgery constructed as an index, was highly associated with flap failure and/or vascular compromise. The vessel architecture and tissue perfusion changes induced by diabetes and therefore the increased risk for flap failure were reported by various authors.[18,19] Moreover, the peripheral arterial occlusive disease affecting mainly

Table 4 Other postoperative complications.

Complication	Number (% from total flaps)	Minor (% from total flaps)	Major (% from total flaps)
Infection	56 (9.9)	5 (0.9)	51 (9)
Partial Flap Necrosis	89 (15.8)	10 (1.8)	79 (14)
Postoperative bleeding	13 (2.3)	1 (0.2)	12 (2.1)
Hematoma	52 (9.2)	9 (1.6)	43 (7.6)
Seroma	6 (1.1)	3 (0.5)	3 (0.5)
Wound dehiscence	46 (8.1)	11 (1.9)	35 (6.2)
Other complication	7 (1.2)	7 (1.2)	0

* Other complications include fistula, wound healing disorder, and tissue volume excess.

Table 5 Univariate risk factor analysis for other postoperative complications.

Characteristic		No Complications	Complications	*P* value
Patient's age		50.47 [9-93]	52.72 [6-87]	0.257
Gender				0.087
	Female	144 (69.9)	62 (30.1)	
	Male	203 (62.7)	121 (37.3)	
ASA score				0.001
	ASA 1	105 (77.8)	30 (22.2)	
	ASA 2	164 (63.3)	95 (36.7)	
	ASA 3	76 (58.9)	53 (41.1)	
	ASA 4	2 (28.6)	5 (71.4)	
Alcohol				0.335
	No	285 (66.1)	146 (33.9)	
	Yes	62 (62.6)	37 (37.4)	
Smoking				0.288
	No	245 (66.9)	121 (33.1)	
	Yes	102 (62.2)	62 (37.8)	
Obesity				0.160
	No	302 (66.7)	151 (33.3)	
	Yes	45 (58.4)	32 (41.6)	
Arterial Hypertension				0.398
	No	262 (66.5)	132 (33.5)	
	Yes	85 (62.5)	51 (37.5)	
Diabetes mellitus				0.043
	No	329 (66.6)	165 (33.4)	
	Yes	18 (50)	18 (50)	
Heart failure				0.785
	No	332 (65.4)	176 (34.6)	
	Yes	15 (68.2)	7 (31.8)	
Cerebrovascular accident				0.006
	No	347 (66)	179 (34)	
	Yes	0 (0)	4 (100)	
Coronary heart disease				0.692
	No	329 (65.7)	172 (34.3)	
	Yes	18 (62.1)	11 (37.9)	
Peripheral arterial vascular disease				0.198
	No	336 (66)	173 (34)	
	Yes	11 (52.4)	10 (47.6)	
COPD or Asthma				0.440
	No	318 (66)	164 (34)	
	Yes	29 (60.4)	19 (39.6)	
Chronic venous insufficiency				.939
	No	341 (65.5)	180 (34.5)	
	Yes	6 (66.7)	3 (33.3)	
Defect etiology				0.664
	Elective	151 (67.1)	74 (32.9)	
	Cancer	101 (62.7)	60 (37.3)	
	Trauma	95 (66)	49 (34)	
Defect Location				0.397
	Head & Neck	115 (64.6)	63 (35.4)	
	Trunk	7 (58.3)	5 (41.7)	
	Breast	51 (71.8)	20 (28.2)	
	Upper Extremity	26 (76.5)	18 (23.5)	
	Lower Extremity	148 (63)	87 (37)	

(*continued on next page*)

Table 5 (*continued*)

Characteristic		No Complications	Complications	*P* value
Flap type				0.063
	ALT	115 (67.3)	56 (32.7)	
	Gracilis	55 (74.3)	19 (25.7)	
	Latissimus dorsi	45 (62.5)	27 (37.5)	
	Fibula	35 (50)	35 (50)	
	Scap/Parascap	28 (62.2)	17 (37.8)	
	DIEP	24 (61.5)	15 (38.5)	
	TRAM	26 (81.3)	6 (18.7)	
	Radialis	8 (72.7)	3 (27.3)	
	Other	11 (68.8)	5 (31.3)	

* COPD=Chronic Obstructive Pulmonary Disease.

Table 6 Multivariate risk factor analysis for other postoperative complications.

	B	EXP(B) = OR	Sig.	95% CI for EXP(B)	
				Lower	Upper
Gender	−.316	.729	.167	.465	1.142
ASA 1			.001		
ASA 2	.787	2.197	.002	1.345	3.589
ASA 3	.956	2.601	.001	1.490	4.542
ASA 4	2.471	11.829	.005	2.122	65.956
Flap Type (ALT)			.012		
Gracilis muscle flap	−.330	.719	.304	.383	1.348
Latissimus dorsi flap	.156	1.169	.605	.647	2.110
Fibula flap	.848	2.334	.004	1.302	4.185
Scapular/Parascapular flap	.433	1.543	.229	.761	3.128
DIEP flap	.573	1.774	.168	.785	4.008
TRAM flap	−.480	.619	.358	.223	1.720
Radialis flap	.098	1.103	.891	.269	4.521
Other flap	.071	1.074	.901	.348	3.319
Constant	−1.356	.258	.084		

the donor vessels also seems to play a significant role in flap failure.[7,19]

The endothelial dysfunction caused by smoking might explain its relation with increased vascular compromise as a contributing factor to our predictability index, but we could not reach the same statistical significance when differentiating between arterial and venous occlusion, as O'Neill et al.[12] did in their study.

Even though the ASA score was used to assess the perioperative risk of patients undergoing surgery, the extreme ASA 4 also seemed to be related with the odds of developing vascular compromise, therefore acting as a different marker for validating our index. Mücke et al.[17] also stated the presence of a significant inverse correlation between the ASA score and free flap survival, but its simplicity was considered a major drawback and does not include etiological factors like the index.

The low flap salvage rate in the patients with arterial thrombosis was also observed in other studies. Nakatsuka et al.[20] recorded 85% failure rate in the arterial thrombosis group and only 40% failure rate in the venous thrombosis group, and Chiu et al.[21] obtained statistically significant values when looking at flap salvage among arterial and venous thrombosis, with a venous thrombosis salvage rate of 68.8%. This can be explained by the easier detection of venous congestion and also by the compensatory oozing through the flap margins and therefore delay of the irreversible damage on the flap. In their head and neck series, they report a thrombosis rate of 4%, while their lower extremity rate was around 19.7%. In our series, 6.2% of the patients recorded vascular compromise, but we could not find any statistically significant difference when looking at defect location. Even though the increased rate of atherosclerosis and vascular damage found among patients with advanced age might suggest an increased thrombosis rate, our study, as well as other authors, does not support this belief,[17,22] making free tissue transfer in elderly a safe and reliable procedure. Arterial thrombosis usually occurs on the first postoperative day.[23] Our results support this finding and also reinforce the fact that arterial thrombosis has a lower salvage rate, with only one flap saved out of the 14 with arterial thrombosis. This difference between arterial and venous occlusion has also been postulated by others,[16,24] with the conclusion that a thrombus will damage the arterial intima, while the vein seems to be more resilient. Overall, our flap salvage rate

Table 7 Complication rates in the literature.

Article	Minor complications (%)	Major complications (%)	Overall surgical complications (%)
Classen et al.[3]	20	19.2	39.2
Wu et al.[30]	-	9.9	-
Wink et al.[29]	18	13.1	29.5
Handschel et al.[27]	-	23	-
Cornejo et al.[26]	-	-	22.35
Pohlenz et al.[28]	35.7	22	-
Chang et al.[25]	-	-	33.3
Wettstein et al.[4]	28	-	40

among the flaps with vascular compromise (54.3%) is close to the one of 59.7% reported by Chiu et al.

In the progression of the index groups, the stepwise increase in the proportion of vascular compromise could be useful in the daily decision-making process when dealing with patients undergoing such complex procedures. The 18.6 times increased incidence of a high-risk patient when compared to a low-risk one to develop vascular compromise and/or flap failure should prompt the surgeon to reassess the indication and may be adopt an alternative surgical strategy.

Postoperative complications

Our minor (7.4%), major (26.9%) and overall surgical complications (32.4 %) situated themselves among the values reported in the literature, as shown in Table 7.[3,4,25-30] It is of course difficult to adequately assess the scope of postoperative complications ranging from donor site complications with a minimal impact on reconstructive outcome to recipient site complication leading in the worst case scenario to flap or reconstructive failure. Nonetheless, the presence of a postoperative complication leading to surgical reintervention definitely has a decisive impact on extremely relevant issues like treatment-associated morbidity and cost.

Even though many studies have tried to identify risk factors involved in postoperative complications,[31-33] there are many contradictory results, and therefore, relevant risk factors are yet to be definitively identified. The only statistically significant variables in the univariate analysis were the ASA score, the presence of diabetes mellitus and history of cerebrovascular accident. Some studies have also reported increased complications in patients with diabetes,[33,34] while others reported no correlation between the disease and the outcome.[14,32] The presence of at least one comorbidity,[8,34] as well as the preoperative medical condition of the patient assessed through the Kaplan-Feinstein index,[35] ASA status,[8] or the Charlson comorbidity index,[36] was found to influence postoperative complications.

In contrast to other studies, where age,[8] smoking,[5] obesity[5] and gender[37] were reported to increase postoperative complications, our study could not identify any statistically significant differences regarding these variables between patients with and without complications. Our results coincide with some of the latest studies, where complications were not influenced by gender,[32] defect location,[15] obesity,[38] smoking[11,14] or age.[11] While isolated variables are unlikely to be reliable predictors for all forms of morbidity and since most of the results in the literature arise from statistical tests that do not take into account the confounding factors,[27,33] we conducted the multivariate analysis. The increased risk of suffering postoperative complications in patients undergoing free fibula transfer in comparison to the ALT flap (Odds Ratio = 2.334, [95% CI] 1.3-4.2) was also reported in other studies, where reintervention, fistula, hematoma and partial necrosis rates were statistically significantly higher in bone-containing free flaps than in pure soft-tissue transfers.[17,30] Moreover, O'Brien et al.[39] and Suh et al.[40] found this type of flap to be associated with higher rates of flap failure.

Limitations

The retrospective design that can account for observer bias is a limitation of our study. Since we envisioned this predictability index, we started collecting prospectively data on free tissue transfer, but this study is still ongoing. We expect the results to further validate our index. Moreover, operative time was not considered because it included the overall operation time, including other procedures such as tumor ablation, osteosynthesis, or intraoperative radiotherapy.

Conclusion

Microvascular free tissue transfer for complex reconstructions has proven to be reliable and safe with a low flap failure rate, although the associated complication risk is high. The patients with postoperative vascular compromise could benefit from an index that estimates this risk. If patients at a high risk of arterial or venous occlusion could be identified preoperatively, additional safety measures could be taken or the surgeon may select an alternative reconstructive strategy. This predictability index could be used in the preoperative setting to improve patient counseling, as well as treatment algorithms.

Declaration of Competing Interest

None declared.

Funding

None.

Ethical approval

The study was conducted according to the Declaration of Helsinki principles and approved by the local Research Ethics Committees.

References

1. McLean DH, Buncke HJ Jr. Autotransplant of omentum to a large scalp defect, with microsurgical revascularization. *Plast Reconstruct Surg* 1972;**49**(3):268–74.
2. Cannady SB, Rosenthal EL, Knott PD, Fritz M, Wax MK. Free tissue transfer for head and neck reconstruction: a contemporary review. *JAMA Fac Plast Surg* 2014;**16**(5):367–73.
3. Classen DA, Ward H. Complications in a consecutive series of 250 free flap operations. *Annal Plast Surg* 2006;**56**(5):557–61.
4. Wettstein R, Schurch R, Banic A, Erni D, Harder Y. Review of 197 consecutive free flap reconstructions in the lower extremity. *J Plast Reconstruct Aesthet Surg: JPRAS* 2008;**61**(7):772–6.
5. Rao S, Stolle EC, Sher S, Lin CW, Momen B, Nahabedian MY. A multiple logistic regression analysis of complications following microsurgical breast reconstruction. *Gland Surg* 2014;**3**(4):226–31.
6. Miller RB, Reece G, Kroll SS, et al. Microvascular breast reconstruction in the diabetic patient. *Plast Reconstruct Surg* 2007;**119**(1):38–45 discussion 46-38.
7. Serletti JM, Higgins JP, Moran S, Orlando GS. Factors affecting outcome in free-tissue transfer in the elderly. *Plast Reconstruct Surg* 2000;**106**(1):66–70.
8. Hwang K, Lee JP, Yoo SY, Kim H. Relationships of comorbidities and old age with postoperative complications of head and neck free flaps: a review. *J Plast Reconstruct Aesthet Surg: JPRAS* 2016;**69**(12):1627–35.
9. Zhang C, Sun J, Zhu H, et al. Microsurgical free flap reconstructions of the head and neck region: Shanghai experience of 34 years and 4640 flaps. *Int J Oral Maxillofac Surg* 2015;**44**(6):675–84.
10. Xiong L, Gazyakan E, Kremer T, et al. Free flaps for reconstruction of soft tissue defects in lower extremity: a meta-analysis on microsurgical outcome and safety. *Microsurgery* 2016;**36**(6):511–24.
11. Reece EM, Bonelli MA, Livingston T, et al. Factors in free fasciocutaneous flap complications: a logistic regression analysis. *Plast Reconstruct Surg* 2015;**136**(1) 54e–58e.
12. O'Neill AC, Haykal S, Bagher S, Zhong T, Hofer S. Predictors and consequences of intraoperative microvascular problems in autologous breast reconstruction. *J Plast Reconstruct Aesthet Surg: JPRAS* 2016;**69**(10):1349–55.
13. Citron I, Galiwango G, Hodges A. Challenges in global microsurgery: a six year review of outcomes at an East African hospital. *J Plast Reconstruct Aesthet Surg: JPRAS* 2016;**69**(2):189–95.
14. Chang EI, Nguyen AT, Hughes JK, et al. Optimization of free-flap limb salvage and maximizing function and quality of life following oncologic resection: 12-year experience. *Ann Surg Oncol* 2016;**23**(3):1036–43.
15. Kwok AC, Agarwal JP. An analysis of free flap failure using the ACS NSQIP database. Does flap site and flap type matter? *Microsurgery* 2016.
16. Yoshimoto S, Kawabata K, Mitani H. Factors involved in free flap thrombosis after reconstructive surgery for head and neck cancer. *Auris Nasus Larynx* 2010;**37**(2):212–16.
17. Mucke T, Rau A, Weitz J, et al. Influence of irradiation and oncologic surgery on head and neck microsurgical reconstructions. *Oral Oncol* 2012;**48**(4):367–71.
18. Rosado P, Cheng HT, Wu CM, Wei FC. Influence of diabetes mellitus on postoperative complications and failure in head and neck free flap reconstruction: a systematic review and meta-analysis. *Head Neck* 2015;**37**(4):615–18.
19. Ishimaru M, Ono S, Suzuki S, Matsui H, Fushimi K, Yasunaga H. Risk factors for free flap failure in 2,846 patients with head and neck cancer: a national database study in Japan. *J Oral Maxillofac Surg: Off J Am Assoc Oral Maxillofac Surg* 2016;**74**(6):1265–70.
20. Nakatsuka T, Harii K, Asato H, et al. Analytic review of 2372 free flap transfers for head and neck reconstruction following cancer resection. *J Reconstruct Microsurg* 2003;**19**(6):363–8 discussion 369.
21. Chiu YH, Chang DH, Perng CK. Vascular Complications and free flap salvage in head and neck reconstructive surgery: analysis of 150 cases of reexploration. *Annal Plast Surg* 2017;**78**(3 Suppl 2):S83–8.
22. Wester JL, Lindau RH, Wax MK. Efficacy of free flap reconstruction of the head and neck in patients 90 years and older. *JAMA Otolaryngol – Head Neck Surg* 2013;**139**(1):49–53.
23. Kroll SS, Schusterman MA, Reece GP, et al. Timing of pedicle thrombosis and flap loss after free-tissue transfer. *Plast Reconstruct Surg* 1996;**98**(7):1230–3.
24. Selber JC, Angel Soto-Miranda M, Liu J, Robb G. The survival curve: factors impacting the outcome of free flap take-backs. *Plast Reconstruct Surg* 2012;**130**(1):105–13.
25. Chang EI, Vaca L, DaLio AL, Festekjian JH, Crisera CA. Assessment of advanced age as a risk factor in microvascular breast reconstruction. *Annal Plast Surg* 2011;**67**(3):255–9.
26. Cornejo A, Ivatury S, Crane CN, Myers JG, Wang HT. Analysis of free flap complications and utilization of intensive care unit monitoring. *J Reconstruct Microsurg* 2013;**29**(7):473–9.
27. Handschel J, Burghardt S, Naujoks C, Kubler NR, Giers G. Parameters predicting complications in flap surgery. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2013;**115**(5):589–94.
28. Pohlenz P, Klatt J, Schon G, Blessmann M, Li L, Schmelzle R. Microvascular free flaps in head and neck surgery: complications and outcome of 1000 flaps. *Int J Oral Maxillofac Surg* 2012;**41**(6):739–43.
29. Wink JD, Nelson JA, Fischer JP, Cleveland EC, Kovach SJ 3rd. Free tissue transfer for complex reconstruction of the lower extremity: experience of a young microsurgeon. *J Reconstruct Microsurg* 2014;**30**(5):349–58.
30. Wu CC, Lin PY, Chew KY, Kuo YR. Free tissue transfers in head and neck reconstruction: complications, outcomes and strategies for management of flap failure: analysis of 2019 flaps in single institute. *Microsurgery* 2014;**34**(5):339–44.
31. Las DE, de Jong T, Zuidam JM, Verweij NM, Hovius SE, Mureau MA. Identification of independent risk factors for flap failure: A retrospective analysis of 1530 free flaps for breast, head and neck and extremity reconstruction. *J Plast, Reconstruct Aesth Surg: JPRAS* 2016;**69**(7):894–906.
32. Mucke T, Ritschl LM, Roth M, et al. Predictors of free flap loss in the head and neck region: A four-year retrospective study with 451 microvascular transplants at a single centre. *J Cranio-maxillo-fac surg: Off Publ Eur Assoc Cranio-Maxillo-Fac Surg* 2016;**44**(9):1292–8.
33. Lo SL, Yen YH, Lee PJ, Liu CC, Pu CM. Factors influencing postoperative complications in reconstructive microsurgery for head and neck cancer. *J Oral Maxillofac Surg: Off J Am Assoc Oral Maxillofac Surg* 2016.

34. Fischer JP, Wink JD, Nelson JA, et al. A retrospective review of outcomes and flap selection in free tissue transfers for complex lower extremity reconstruction. *J Reconstruct Microsurg* 2013;**29**(6):407–16.
35. Dassonville O, Poissonnet G, Chamorey E, et al. Head and neck reconstruction with free flaps: a report on 213 cases. *Eur Arch Oto-rhino-laryngol: Off J Eur Feder Oto-Rhino-Laryngol Soc (EUFOS): Affil German Soc Oto-Rhino-Laryngol – Head Neck Surg* 2008;**265**(1):85–95.
36. Khouri RK, Cooley BC, Kunselman AR, et al. A prospective study of microvascular free-flap surgery and outcome. *Plast Reconstruct Surg* 1998;**102**(3):711–21.
37. Sanati-Mehrizy P, Massenburg BB, Rozehnal JM, Ingargiola MJ, Hernandez Rosa J, Taub PJ. Risk factors leading to free flap failure: analysis from the national surgical quality improvement program database. *J Craniofac Surg* 2016;**27**(8):1956–64.
38. de la Garza G, Militsakh O, Panwar A, et al. Obesity and perioperative complications in head and neck free tissue reconstruction. *Head Neck* 2016;**38**(Suppl 1):E1188–91.
39. O'Brien CJ, Lee KK, Stern HS, et al. Evaluation of 250 free-flap reconstructions after resection of tumours of the head and neck. *Austral N Zeal J Surg* 1998;**68**(10):698–701.
40. Suh JD, Sercarz JA, Abemayor E, et al. Analysis of outcome and complications in 400 cases of microvascular head and neck reconstruction. *Arch Otolaryngol – Head Neck Surg* 2004;**130**(8):962–6.