Article published online: 2022-03-11

Microsurgical Reconstruction in an Orthopedic Hospital: Indications and Outcomes in Adults

Reconstrução microcirúrgica em um hospital ortopédico: Indicações e desfechos em adultos

Raquel Bernardelli Iamaguchi[1] Lucas Sousa Macedo[1] Alvaro Baik Cho[1] Marcelo Rosa de Rezende[1] Rames Mattar Júnior[1] Teng Hsiang Wei[1]

[1] Hand Surgery and Reconstructive Microsurgery Group, Instituto de Ortopedia e Traumatologia, Hospital das Clínicas, Faculdade de Medicina da Universidade de São Paulo, São Paulo, SP, Brazil

Address for correspondence Raquel Bernardelli Iamaguchi, M.D., MSc., PhD., Rua Dr. Ovídio Pires de Campos, 333, 05403-010, São Paulo-SP, Brazil (e-mail: rbiamaguchi@gmail.com).

Rev Bras Ortop 2022;57(5):772–780.

Abstract

Objective Advances in reconstructive microsurgery in orthopedic surgery provided better functional and aesthetic results and avoided many indications for amputation. In high-volume trauma and orthopedic hospitals, microsurgical reconstruction is essential to reduce costs and complications for these complex orthopedic defects. We describe a microsurgical approach to traumatic wounds, tumor resection, bone defects, and free muscle transfer, performed by an orthopedic microsurgery unit. The objective of the present study was to evaluate predictor factors for outcomes of microsurgical flaps for limb reconstruction, and to provide a descriptive analysis of microsurgical flaps for orthopedic indications.

Methods Cross-sectional prospective study that included all consecutive cases of microsurgical flaps for orthopedic indications from 2014 to 2020. Data were collected from personal medical history, intraoperative microsurgical procedure, and laboratory blood tests. Complications and free-flap outcomes were studied in a descriptive and statistical analysis.

Results We evaluated 171 flaps in 168 patients; the indications were traumatic in 66% of the patients. Type III complications of the Clavien-Dindo Classification were observed in 51 flaps. The overall success rate of the microsurgical flaps was 88.3%. In the multivariate analysis, the risk factors for complications were ischemia time $\geq$ 2 hours ($p = 0.032$) and obesity ($p = 0.007$). Partial flap loss was more common in patients with thrombocytosis in the preoperative platelet count ($p = 0.001$).

Keywords

- free tissue flaps
- trauma
- microsurgery
- orthopedic procedures
- tissue transplantation

Work developed at the Hand Surgery and Reconstructive Microsurgery Group of the Instituto de Ortopedia e Traumatologia do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, São Paulo, SP, Brazil.

received
February 23, 2021
accepted after revision
May 18, 2021
published online
March 11, 2022

DOI https://doi.org/10.1055/s-0041-1735946.
ISSN 0102-3616.

Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Conclusion The independent risk factors for complications of microsurgical flaps for limb reconstruction are obesity and flap ischemia time $\geq$ 2 hours, and presence of thrombocytosis is a risk factor for partial flap loss.

Resumo

Objetivo Os avanços da microcirurgia reconstrutiva na cirurgia ortopédica proporcionaram melhores resultados funcionais e estéticos, evitando as muitas indicações de amputação. Nos hospitais de ortopedia e traumatologia com um grande volume de atendimento, a reconstrução microcirúrgica é essencial, a fim de reduzir os custos e as complicações destes complexos defeitos ortopédicos. Descrevemos uma abordagem microcirúrgica para feridas traumáticas, ressecção tumoral, defeitos ósseos e transferência muscular livre realizada por uma unidade ortopédica especializada em microcirurgia. O objetivo do presente estudo é avaliar os fatores preditivos de resultados dos retalhos microcirúrgicos na reconstrução dos membros, fornecendo uma análise descritiva dos retalhos microcirúrgicos para as indicações ortopédicas.

Métodos Estudo prospectivo transversal, que incluiu todos os casos consecutivos de retalhos microcirúrgicos com indicação ortopédica de 2014 a 2020. Foram coletados os dados do histórico clínico pessoal, procedimentos microcirúrgicos intraoperatórios e exames laboratoriais. As complicações e os desfechos de retalho livre foram estudados mediante uma análise descritiva e estatística.

Resultados Avaliamos 171 retalhos em 168 pacientes. A indicação mais frequente para a realização de um retalho microcirúrgico foi a traumática, em 66% dos pacientes. Foram observadas complicações cirúrgicas em 51 retalhos, conforme a classificação de Clavien-Dindo do tipo III. A taxa de êxito global dos retalhos microcirúrgicos foi de 88,3%. Na análise multivariada, foram identificados como fatores de risco para complicações tempo de isquemia $\geq$ 2 horas ($p = 0{,}032$) e obesidade ($p = 0{,}007$). A perda parcial do retalho foi mais comum em pacientes com trombocitose, com contagem de plaquetas pré-operatória ($p = 0{,}001$).

Conclusão Os fatores de risco independentes para complicações de retalhos microcirúrgicos para a reconstrução de membro são obesidade e tempo de isquemia do retalho $\geq$ 2 horas, e a presença de trombocitose como fator de risco para perda parcial do retalho.

Palavras-chave
- retalhos de tecido biológico
- trauma
- microcirurgia
- procedimentos ortopédicos
- transplante de tecidos

Introduction

Microsurgical flaps are established as one important tool in reconstructing traumatic complex defects of the limbs. In some cases, this tool can provide better aesthetic and functional results, as an immediate and definitive coverage, following an old concept of fix and flap[1] or a newer concept of reconstructive elevator.[2]

The treatment of complex lesions of the musculoskeletal system has evolved to a combination of orthopedic techniques allied with free-flap transfer, described as orthoplastic reconstruction in traumatic cases.[3,4] Most of these complex cases need to be transferred to a referral hospital, thus prolonging hospitalization period and increasing costs for the public health system.[5]

Microsurgical flaps for limb reconstruction are either functional or an attempt to spare limb surgery, so they are usually performed under circumstances that can be less than ideal to reduce complications. Although patients with complex injuries of the limbs are referred to orthopedic centers, microsurgical flaps are usually performed by plastic surgery teams. We describe the experience of an orthopedic microsurgery group providing combined early treatment to reduce healthcare costs and achieve better functional results. The objective of the present study is to describe the role of reconstructive microsurgery in an orthopedic department with indications and results of free flaps, with combined treatment for orthopedic injuries, through descriptive analysis of the cases and evaluation of predictive factors that influence the incidence of complications of microsurgical flaps in the musculoskeletal apparatus.

Patients and Methods

A prospective observational study with consecutive inclusion of all patients submitted to microsurgical flaps in an orthopedic department. The main indications were

traumatic wounds with exposure of bone and/or of neurovascular bundle that could not be covered with pedicle flaps or skin grafts, long bone defects > 6 cm, and free functional muscular transfers for upper limbs. The Exclusion criteria were patients < 18 years old and insufficient postoperative data at follow-up. The Ethical and Scientific Committee approved the present work (CAAE no. 42679515.2.0000.0068). Informed consent was obtained from all individual participants included in the present study, and the study was performed in accordance with the Declaration of Helsinki.

The database included patient demographics (age, gender, and comorbidities) and laboratory analysis of hemoglobin and platelet count in blood levels. The following intraoperative data were recorded: type of flap, recipient vessels, type of arterial anastomosis, number of venous anastomoses, intraoperative ischemia time of free flap (time elapsed between the section of the pedicle in the donor area and the release of claps of the artery and at least one vein with flap perfusion), and participation of the training resident performing microanastomosis.

Complications included were (type III of the Clavien-Dindo classification):[6] deep infection that required surgical debridement, hematoma that required surgical drainage, dehiscence, take-back flap, amputation, and partial or total flap loss.

Table 1 Epidemiological data

Gender	Number of flaps (%)
Male	130 (76%)
Female	41 (24%)
Indications	
Trauma	109 (63.7%)
Brachial plexus lesion	42 (24.6%)
Tumor	10 (5.8%)
Burn scar	6 (3.5%)
Others	4 (2.4%)
Comorbidities (isolated or associated)	
Obesity	34 (19.9%)
Mean obesity BMI = 33.0 kg / m^2	
Mean general group BMI = 26.13 kg / m^2	
Smokers	16 (9.3%)
Systemic hypertension	11 (6.4%)
Diabetes mellitus	9 (5.3%)
Other	5 (3.0%)
171 free flaps in 166 patients	

Abbreviation: BMI, body mass index.

Statistical Analysis

Statistical analyses were performed in IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA). Anemia (moderate or severe) was defined as hemoglobin < 11 g/dL (World Health Organization [WHO])[7] and thrombocytosis as platelets count $\geq 450 \times 10^9$/L).[8] Obesity was defined as presence of body mass index (BMI) $\geq$ 30 kg/m^2 (WHO). Traumatic cases, excluding 6 cases of toe-to-hand transfer, were divided into chronic (operated > 21 days after the traumatic event) and acute (operated within $\leq$ 21 days after the trauma). Next, these groups were subdivided into 2 groups: $\leq$ 7 days after the trauma or > 7 days. Qualitative data were analyzed by the Pearson chi-squared test or by the Fisher exact test when the frequency was lower than expected. The Mann-Whitney U-test was used for quantitative nonparametric data. Ischemia time cutoff was determined by the Youden index, in receiver operating characteristic (ROC) curve. Binary logistic regression was then conducted on the variables with $p<0.20$ in the univariate analysis and included one independent variable in the logistic regression for each 10 cases of occurrence of complication. The backward algorithm was used.

Results

A total of 171 microsurgical flaps in 166 patients, performed between 2014 and 2020, were studied (►**Table 1**). The mean age was 35.2 years old (19 to 69 years old, standard deviation [SD]: 11.3). The most common indication for microsurgical reconstruction was traumatic lesion in 109 patients (►**Fig. 1**); among them, there were 6 cases of toe-to-hand and 103 cases of limb reconstruction, with 50 patients treated within 21 days after the traumatic event (19 patients within 7 days after the traumatic event) and 53 patients after 21 days, or chronic cases (►**Table 2**).

The age of the patient did not influence the presence of complications ($p = 0.996$).

Fifty patients had anemia in the preoperative evaluation. The average hemoglobin values were 13.1 g/dL. Postoperatively, 90 patients (52.6%) had anemia, and the average hemoglobin level was 10.4 g/dL (SD = 1.8 g/dL). Analysis of platelet count showed that 19 patients had preoperative thrombocytosis, with 307×10^9/L in average (SD = 146×10^9/L).

The most common flap was the anterolateral thigh (ALT) flap in 31% of the cases (►**Figs. 2** and **3**). Intraoperative data are described in ►**Table 3**.

A vein graft was necessary for anastomosis in nine patients. The comitantes or deep venous system was chosen in 77.2% of the cases. The mean ischemia time was 124.49 minutes (SD: 45.2 minutes). Residents performed at least 1 arterial or venous anastomosis (or both) in 141 flaps (82.5%).

Clavien-Dindo type III complications were observed in 51 flaps, which are described in ►**Fig. 4**. In four patients, a second free flap was required, and in one of these patients a third free flap was performed (►**Fig. 5**).

Increased ischemia time had a statistically significant association with complication rates. The area under the ROC curve (►**Fig. 6**) was 0.617 and the cutoff point was determined based on the Youden criteria of 2 hours (71% sensitivity and 59% specificity). Based on this cutoff point, the time of ischemia was categorized into 2 groups: > 2 hours and $\leq$ 2 hours.

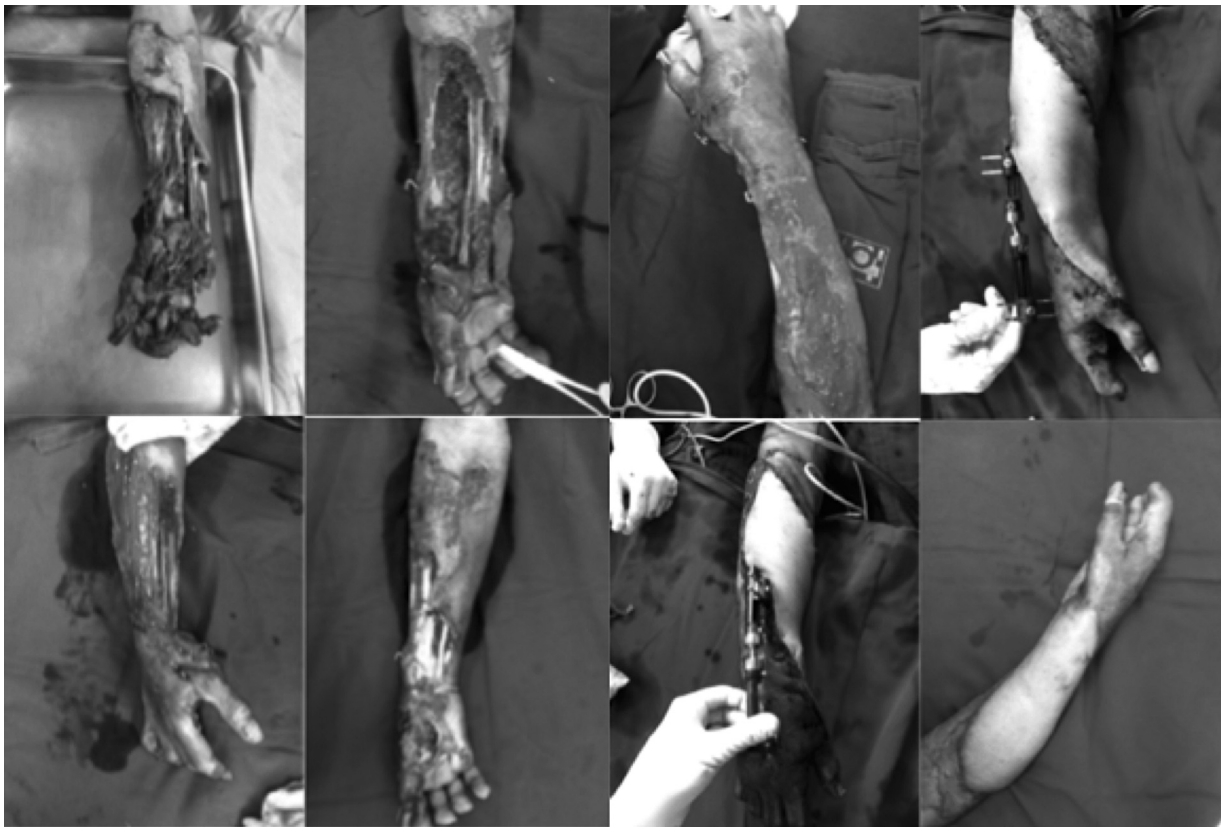

Fig. 1 Male, 67 years old, traumatic complex wound in the forearm, submitted to ALT flap, proximal row carpectomy and external fixation of the wrist.

Table 2 Traumatic cases

Type of flap	Number of flaps (%)
ALT	47 (45.6%)
Latissimus dorsi	25 (24.3%)
Vascularized fibular flap	14 (13.6%)
Lateral arm	8 (7.8%)
Parascapular	2 (1.9%)
Others	7(6.8%)
Type of arterial anastomosis	
End-to-side	73 (70.9%)
End-to-end	30 (29.1%)
Number of venous anastomoses	
1 vein	58 (56.3%)
2 veins	45 (43.7%)
Time of free flap from trauma	
< 21 days	50 (48.5%)
> 21 days	53 (51.5%)
103 free flaps in traumatic cases	

Abbreviation: ALT: anterolateral thigh flap.

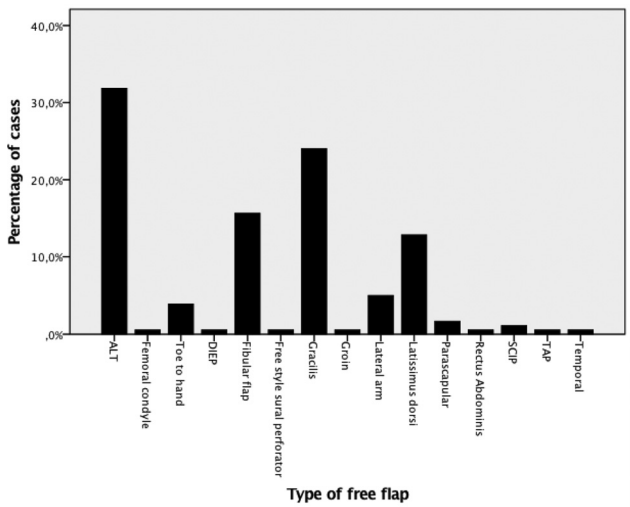

Fig. 2 Type of microsurgical flap according to the donor area.

►**Table 4** summarizes the univariate and multivariate analyses of the risk factors for complications. Ischemia > 2 hours and obesity remained as independent risk factors. Patients with complications had longer hospitalization days ($p < 0.001$). Residents performing the anastomosis did not influence the incidence of complications ($p = 0.982$), including when performing end-to-side anastomosis ($p = 0.217$). Excluding obesity, the presence of other comorbidities did not influence the incidence of complications ($p = 0.982$), including patients with diabetes mellitus ($p = 0.813$).

For partial flap loss to occur, the presence of thrombocytosis ($p = 0.003$), preoperative anemia ($p = 0.013$), and end-to-

Fig. 3 Female, 32 years old, chronic traumatic complex defect of tibia, submitted to bone shortening and intramedullary internal fixation and ALT flap.

Table 3 Intraoperative data

Type of flap	Number of flaps (%)
ALT	53 (31%)
Free gracilis	45 (26.3%)
Vascularized fibular flap	21 (12.3%)
Latissimus dorsi	26 (15.2%)
Lateral arm	10 (5.8%)
Others	16 (9.4%)
Type of arterial anastomosis	
End-to-side	88 (51.5%)
End-to-end	83 (48.5%)
Number of venous anastomosis	
1 vein	101 (59.1%)
2 veins	70 (40.9%)
171 free flaps in 166 patients	

Abbreviation: ALT: anterolateral thigh flap.

side (ETS) arterial anastomosis ($p = 0.009$) were statistically significant in the univariate analysis; thrombocytosis was the only independent risk factor in the multivariate analysis (0.001). The risk factor for total flap loss was the indication of vein graft for anastomosis ($p = 0.012$).

The indication of take-back flap was associated with a higher incidence of total flap loss ($p < 0.001$) and the independent risk factor for take-back flap was obesity in multivariate analysis. The statistical analysis is summarized in ►**Table 5**.

In the group of traumatic cases, patients submitted to microsurgical reconstruction > 7 days after the traumatic event had a higher rate of complications ($p = 0.043$) and no difference of flap survival ($p = 0.64$). No difference between chronic cases (operated > 21 days after the trauma) and acute cases for complications and survival rate was observed ($p = 0.3$ and $p = 0.93$, respectively).

The success rate of the microsurgical flaps was 88.3%, with a 3% amputation rate.

Discussion

Microsurgical reconstruction in orthopedic surgery demands specialized technical support, high-cost materials, the involvement of multiprofessional health workers, and requires long hospitalization periods.[9] Pohlenz et al.[10] suggest that the success rate is due to experience and postoperative support in a high-volume hospital. In our study, as well as in the literature,[11–13] we observed an increased incidence of male young patients with traumatic injuries, especially due to traffic accidents (53% of the cases). In these cases, it is important to perform a combined treatment with bone stabilization or reconstruction with skin coverage, with simultaneous teams. To reduce the number of surgeries, infection rates, and hospitalization time,[14] it is important

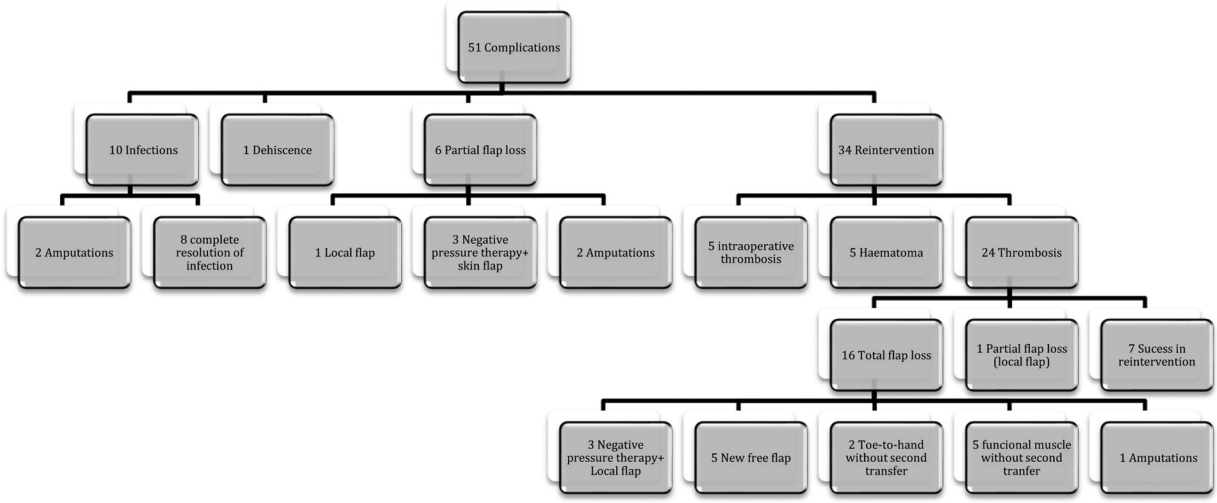

Fig. 4 Number of cases of microsurgical flaps according to the presence of complications.

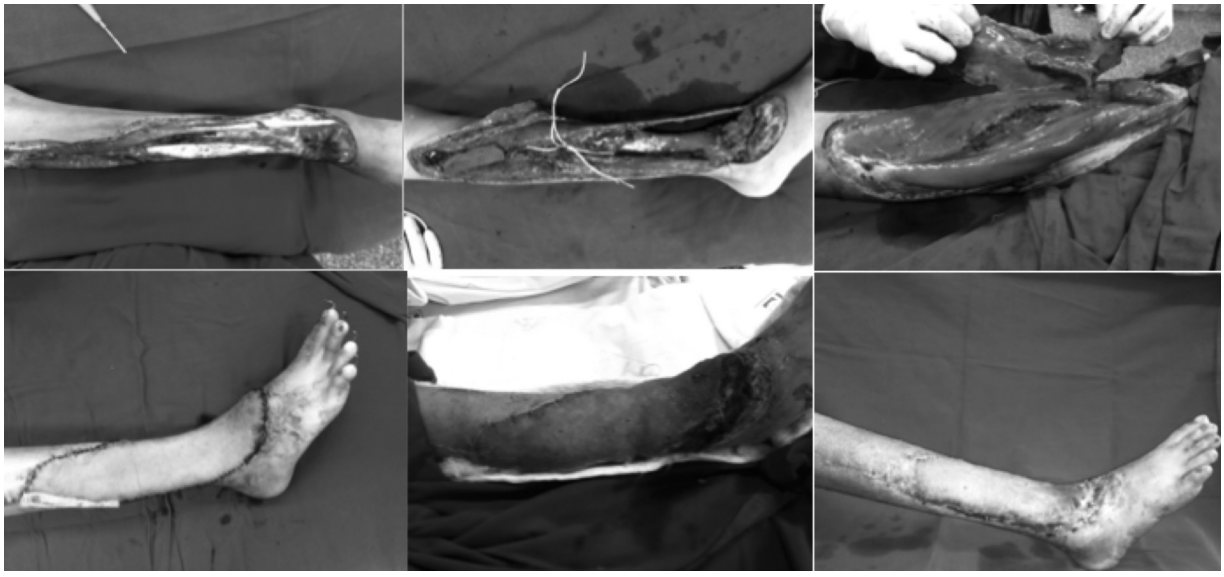

Fig. 5 Male patient, 28 years old, submitted to oncologic resection and ALT flap. Complication of partial flap loss, treated with negative pressure wound therapy and skin graft.

to establish reconstructive microsurgery centers in orthopedic hospitals.

We did not observe influence of advanced age on complications, as evidenced by other papers.[15,16] In our orthopedic hospital, free flaps in elderly are not common, since oncologic reconstruction is less common than trauma and only 6 patients $>$ 60 years old were operated on with no occurrence of complications. In selected patients requiring microsurgical flap for limb salvage, age should not be a determinant for absolute contraindication[17]; the success rates in older patients can be similar to those in young patients through adequate preoperative planning and clinical stabilization of the patient.

When we analyzed the presence of comorbidities, obesity was an independent risk factor for complications, including take-back flap, a result similar to that obtained by Cleveland et al.,[18] who observed an increased incidence of total flap loss. Obese patients have a greater association with cardiovascular diseases and metabolic disorders, as well as inherent difficulties for anesthesia, such as control of drug delivery and greater volumes administered. From the surgical point of view, these patients imply greater technical difficulty due to increased blood loss and depth of the structures.

Presence of anemia did not influence the results in our study. Hill et al.[19] demonstrate an increase in total flap loss and vascular thrombosis in patients with anemia. In situations of hypotension and hypovolemia, peripheral vasoconstriction occurs, which causes reduced flow that is harmful to microsurgical flaps. Therefore, we suggest maintaining hemoglobin values $>$ 10 g/dL, which justifies the high indication for blood transfusion in our series (60% of the patients).

Performing single or two-venous anastomosis to drain free flap did not influence the incidence of complications in our study; however, an increase in take-back flap was observed in patients with only 1 venous anastomosis (22 *versus* 15% with two-venous anastomoses), but it was not statistically

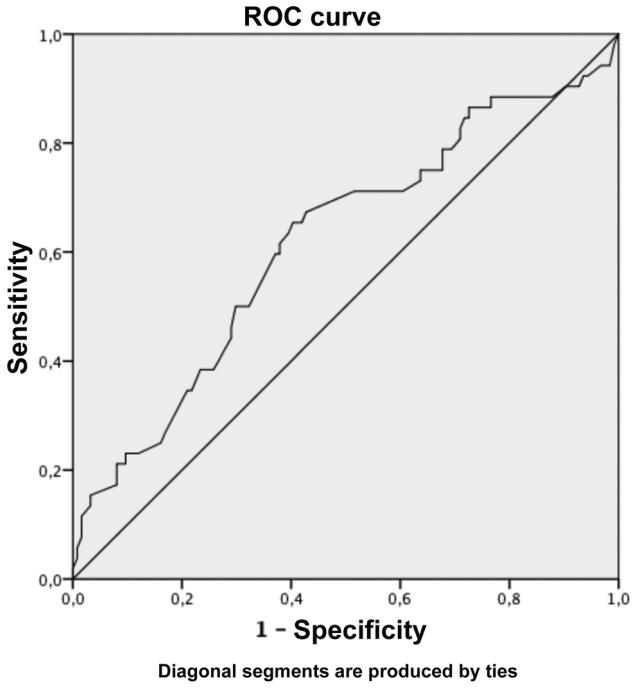

Fig. 6 ROC curve characteristics with analysis of ischemia time related to complications.

significant. Ross et al.[20] observed better outcomes with free-flap reconstruction when two-venous anastomosis was performed, and Dornseifer et al.[21] described a higher incidence of take-back flap with single-venous anastomoses. As venous thrombosis is the most common vascular complication in microsurgical flaps, we suggest that when the flap has more than one venous system for drainage and when the operative time is not long, two-venous anastomoses should be performed.

When comparing the type of arterial anastomoses, we observed that end-to-side (ETS) anastomosis had a higher incidence of partial flap loss in the univariate analysis. Tsai et al.[22] concluded that end-to-end and ETS anastomoses have similar flap survival rates. We recommend ETS anastomosis to preserve the main arteries of the limbs and when anatomical variations are expected, such as vessel size discrepancy,[23,24] although ETS anastomosis requires greater technical skill and probably a higher learning curve in training hospitals with residency in microsurgery.

Our orthoplastic unit has a residency of microsurgery in the orthopedic hospital, and the residents perform microvascular anastomosis (82% of the flaps) under supervision of more experienced microsurgeons. We observed an increased indication of take-back flap for cases operated by the resident (21 *versus* 6% when operated by the senior surgeon), but it was not statistically significant, and the presence of complications did not interfere in the success rates of microsurgical flaps. In the literature, some studies[25–27] observe a higher percentage of complications and increased length of hospitalization when residents perform free flaps. Recalling our residency program, training new surgeons is essential for the future of microsurgery and, in this path, public and university hospitals with high demand for complex orthopedic cases will have resources to perform specialized microsurgical reconstruction when necessary.

Treatment of traumatic limb injuries with microsurgical flaps has higher percentages of total flap loss and complications[28–30] than flaps for head and neck or breast reconstruction,[15] due to the quality of the recipient vessels and posttraumatic thrombophilia. Our hospital is a referral center for trauma and, commonly, patients with extensive limb injuries requiring microsurgical reconstruction are referred

Table 4 Multivariate analysis of risk factors for complications of microsurgical flaps

	Univariate	Multivariate		
	p-value	OR	95%CI	*p-value*
Ischemia time > 2 hours	0.007	2.2	1.1–4.6	**0.032**
Vein graft	0.014	3.8	1.1–16.7	0.08
ETS artery	0.112	1.8	0.9–3.8	0.12
BMI $\geq$ 30 kg/m^2	0.004	2.5	1.1–5.7	**0.007**

Abbreviations: BMI, body mass index; CI, confidence interval; ETS, end-to-side; OR, odds ratio or odds ratios.

Table 5 Multivariate analysis of risk factors for take-back flap of microsurgical flaps

	Univariate	Multivariate		
	p-value	OR	95%CI	*p-value*
Ischemia time > 2 hours	0.004	2.3	1.0–6.4	0.07
Resident performing anastomosis	0.093	3.5	0.8–16.6	0.11
One venous anastomosis	0.323	1.4	0.6–3.3	0.44
Vein graft	0.005	4.2	10.9–18.7	0.06
BMI $\geq$ 30 kg/m^2	0.031	2.7	1.0–6.9	**0.04**

Abbreviations: BMI, body mass index; CI, confidence interval; OR, odds ratio or odds ratios.

for treatment in our reconstructive microsurgery group after the ideal timing for early reconstruction: < 50% of free flaps are performed within 21 days after the traumatic event, and < 20% within 7 days after the trauma. The complication rates were higher for patients operated > 7 days after the trauma with similar flap survival. Therefore, it is important to emphasize that the presence of a team prepared for microsurgical reconstruction in an orthopedic hospital can reduce postoperative complications, reducing hospital stay and promoting a reduction in costs for public health.

In our study, intraoperative ischemia time > 2 hours was an independent risk factor for free-flap complications. The influence of a longer ischemia time on complications of microsurgical flaps was first demonstrated in breast reconstructions.[15] The longer ischemia time can be associated with several factors, mainly those related to the recipient area and vessels due to the complexity of wounds. This risk factor demonstrates the importance of controlling intraoperative variables, limiting ischemia time, and thus reducing the highest rates of complications in orthopedic reconstructions.

The final success rate of our series of microsurgical reconstruction of limbs resembles studies on microsurgical flaps in published papers, with an overall success rate of 88.3%.

A limitation of the present study is that some technical surgical choices, such as recipient vessels, number of veins, and type of arterial anastomoses, may present bias, since they may be affected by the severity of the wound and by the personal decision of the senior surgeon performing the surgery. The number of cases in the present study is a limitation for the statistical analysis of the influence of individual comorbidities on the incidence of complications. However, the present study is a cross-sectional study with prospective inclusion of all cases of orthoplastic reconstruction of limbs, which allowed drawing some conclusions with an acceptable power analysis.

Conclusion

The independent risk factors for complications of microsurgical flaps for limb reconstruction are obesity and flap ischemia time > 2 hours, and presence of thrombocytosis is a risk factor for partial flap loss. In an orthopedic hospital with reconstructive microsurgery, we recommend being aware of these risk factors to prevent complications.

Financial Support
The present study received no financial support from public, commercial, or not-for-profit sources.

Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Godina M. Early microsurgical reconstruction of complex trauma of the extremities. Plast Reconstr Surg 1986;78(03):285–292
2 Gottlieb LJ, Krieger LM. From the reconstructive ladder to the reconstructive elevator. Plast Reconstr Surg 1994;93(07):1503–1504
3 Wagels M, Rowe D, Senewiratne S, Read T, Theile DR. Soft tissue reconstruction after compound tibial fracture: 235 cases over 12 years. J Plast Reconstr Aesthet Surg 2015;68(09):1276–1285
4 Heitmann C, Levin LS. The orthoplastic approach for management of the severely traumatized foot and ankle. J Trauma 2003;54(02): 379–390
5 Dos Anjos KC, de Rezende MR, Mattar R Jr. Social and hospital costs of patients admitted to a university hospital in Brazil due to motorcycle crashes. Traffic Inj Prev 2017;18(06):585–592
6 Clavien PA, Barkun J, de Oliveira ML, et al. The Clavien-Dindo classification of surgical complications: five-year experience. Ann Surg 2009;250(02):187–196
7 World Health Organization WHO. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity vitamin and mineral nutrition information system. Geneva: World Health Organization 2011. Available from: https://www.who.int/vmnis/indicators/haemoglobin/en/
8 Harrison CN, Bareford D, Butt N, et al. British Committee for Standards in Haematology. Guideline for investigation and management of adults and children presenting with a thrombocytosis. Br J Haematol 2010;149(03):352–375
9 Al-Dam A, Zrnc TA, Hanken H, et al. Outcome of microvascular free flaps in a high-volume training centre. J Craniomaxillofac Surg 2014;42(07):1178–1183
10 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(01):89–92
11 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 Reconstr Microsurg 2013;29 (06):407–416
12 Lazo DAA, Zatit SCA, Colicchio O, Nishimura MT, Mazzer N, Barbieri CH. Reconstrução dos membros com retalhos microcirúrgicos na urgência: experiência de 10 anos com 154 casos consecutivos. Rev Soc Bras Cir Plást 2005;20(02):88–94
13 Severo AL, Scorsatto C, Valente EB, Lech OLC. Retalhos para reconstrução de perdas musculocutâneos em membros inferiores: análise de 18 casos. Rev Bras Ortop 2004;39(10):578–589
14 Mathews JA, Ward J, Chapman TW, Khan UM, Kelly MB. Single-stage orthoplastic reconstruction of Gustilo-Anderson Grade III open tibial fractures greatly reduces infection rates. Injury 2015; 46(11):2263–2266
15 Chang EI, Chang EI, Soto-Miranda MA, et al. Comprehensive evaluation of risk factors and management of impending flap loss in 2138 breast free flaps. Ann Plast Surg 2016;77(01):67–71
16 Jubbal KT, Zavlin D, Suliman A. The effect of age on microsurgical free flap outcomes: An analysis of 5,951 cases. Microsurgery 2017;37(08):858–864
17 Malata CM, Cooter RD, Batchelor AG, Simpson KH, Browning FS, Kay SP. Microvascular free-tissue transfers in elderly patients: the leeds experience. Plast Reconstr Surg 1996;98(07):1234–1241
18 Cleveland EC, Fischer JP, Nelson JA, Wink JD, Levin LS, Kovach SJ 3rd. Free flap lower extremity reconstruction in the obese population: does weight matter? J Reconstr Microsurg 2014;30(04): 263–270
19 Hill JB, Patel A, Del Corral GA, et al. Preoperative anemia predicts thrombosis and free flap failure in microvascular reconstruction. Ann Plast Surg 2012;69(04):364–367
20 Ross GL, Ang ES, Lannon D, et al. Ten-year experience of free flaps in head and neck surgery. How necessary is a second venous anastomosis? Head Neck 2008;30(08):1086–1089
21 Dornseifer U, Kleeberger C, Kimelman M, et al. Less is more? Impact of single venous anastomosis on the intrinsic transit time of free flaps. J Reconstr Microsurg 2017;33(02):137–142
22 Tsai YT, Lin TS. The suitability of end-to-side microvascular anastomosis in free flap transfer for limb reconstruction. Ann Plast Surg 2012;68(02):171–174

23 Cho EH, Garcia RM, Blau J, et al. Microvascular anastomoses using end-to-end versus end-to-side technique in lower extremity free tissue transfer. J Reconstr Microsurg 2016;32(02):114–120
24 Heidekrueger PI, Ninkovic M, Heine-Geldern A, Herter F, Broer PN. End-to-end versus end-to-side anastomoses in free flap reconstruction: single centre experiences. J Plast Surg Hand Surg 2017; 51(05):362–365
25 le Nobel GJ, Higgins KM, Enepekides DJ. Predictors of complications of free flap reconstruction in head and neck surgery: Analysis of 304 free flap reconstruction procedures. Laryngoscope 2012;122(05):1014–1019
26 Raval MV, Wang X, Cohen ME, et al. The influence of resident involvement on surgical outcomes. J Am Coll Surg 2011;212(05): 889–898
27 Hirche C, Kneser U, Xiong L, et al. Microvascular free flaps are a safe and suitable training procedure during structured plastic surgery residency: A comparative cohort study with 391 patients. J Plast Reconstr Aesthet Surg 2016;69(05):715–721
28 Hill JB, Vogel JE, Sexton KW, Guillamondegui OD, Corral GAD, Shack RB. Re-evaluating the paradigm of early free flap coverage in lower extremity trauma. Microsurgery 2013;33(01):9–13
29 Rinker B, Amspacher JC, Wilson PC, Vasconez HC. Subatmospheric pressure dressing as a bridge to free tissue transfer in the treatment of open tibia fractures. Plast Reconstr Surg 2008;121 (05):1664–1673
30 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(06):511–524