Journal of Plastic, Reconstructive & Aesthetic Surgery (2019) 72, 555–564

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

Free tissue transfer with the free rectus abdominis flap in high-risk patients above 65 years: A retrospective cohort study

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Received 21 October 2018; accepted 6 January 2019

KEYWORDS
Rectus abdominis muscle flap;
Elderly;
Multimorbid

Summary *Background:* Though technically feasible, free tissue transfer carries the risk of perioperative morbidity and mortality in elderly patients. To minimize the operative treatment time and complication rates, we choose the rectus abdominis muscle (RAM) flap.
Methods: Between 2012 and 2017, 34 patients (mean age: 74±7 years, range: 65–89 years) with comorbidities underwent defect reconstruction with a free RAM flap. Recipient-sites were: lower extremity (65%), trunk (18%), upper extremity (12%), and head and neck (6%).
Results: The ASA status was 2 in 11 patients, 3 in 21 patients, and 4 in 2 patients. Twenty patients (59%) received additional vascular surgery. Three patients (9%) underwent simultaneous restoration of fractures. The mean operative time (OT) was 325±75 min. There was no total flap loss. Partial flap loss occurred in one patient (3%). The incidence of surgical and medical complications was 32% and 38%: 11 patients experienced a total of 22 surgical complications, of which 15 were major (requiring additional surgery) and 7 minor (conservative treatment). One patient died postoperatively because of progressive respiratory failure. Prolonged OT was highly associated with hematoma formation requiring re-operation ($p = 0.01$). ASA status was a significant predictor for postoperative critical care monitoring ($p = 0.03$). Reconstruction was successful in 31 out of 34 patients (91%) during a mean follow-up time of 17.7 ± 8.8 months (range: 2–51 months).

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https://doi.org/10.1016/j.bjps.2019.01.005
1748-6815/

Conclusion: The free RAM flap has proven as a reliable and efficient tool in the armamentarium of reconstructive microvascular surgeons with some advantages in the treatment of multimorbid patients older than 65 years.

Introduction

Because of the demographic changes, the number of elderly and multimorbid patients is steadily increasing. These patients represent a significant challenge to all surgical disciplines due to diminished functional capacities of all vital organs.[1,2] For soft tissue reconstruction, microvascular free flap transfer is widely regarded safe and reliable with failure rates varying between 4.4% and 6.0%.[3,4] However, it is technically demanding, time consuming, and often debilitating on elderly and multimorbid patients.[3-5] Thus, there exists a dilemma when a defect cannot be reconstructed with reasonable efforts, such as local or pedicled flaps. Even though technically feasible, free flap transfer may then carry a distinct risk of perioperative morbidity and mortality in these patients.[6] In this context, the American Society of Anesthesiologists (ASA) score has been identified as the most important determinant of postoperative complications after microsurgical procedures.[7-9] To minimize operative treatment time (OTT) and thus complication rates, we choose the free rectus abdominis muscle (RAM) flap because we think it has some advantages. Flap harvest is very straightforward with the patient in supine position. Operation in supine position also allows a two-team-approach with simultaneous preparation of the donor- and recipient-site (flap harvest, treatment of extremity fractures, and preparation of the recipient vessels). Further advantages are: highly vascularized soft-tissue, large caliber of donor vessels, good flap size and pedicle length, easy flap positioning, low donor-site morbidity, and good long-term functional and cosmetic results. Furthermore, we think that the free RAM flap is ideally suited for transfer in combination with vascular bypasses or arteriovenous loops because of the large diameter of the inferior epigastric vessels, the well-vascularized muscle, and the low intrinsic vascular resistance. However, the potential disadvantages have relegated it to a second-line flap. We therefore evaluated free flap surgery with the free RAM flap in comorbid elderly patients in whom free flap surgery was the only reconstructive option but associated with the distinct risk of perioperative morbidity and mortality.

Methods

Patients

We conducted a retrospective single-center retrospective study between December 2012 and May 2017, and identified 34 patients (11 female, 23 male) with a mean age of 74 ± 7 years (range: 65 - 89 years; median: 75 years), who underwent soft-tissue reconstruction using free RAM flaps. The reasons for flap choice were as follows: patients aged older than 65 years with diminished functional capacity, and the presence of multimorbidity or multiple chronic diseases (two or more chronic conditions, e.g., diabetes mellitus, renal disease, chronic pulmonary disease, and peripheral vascular disease) in whom local or pedicled flaps were not suitable for defect reconstruction. In detail, 20 free RAM flaps with perforator-based skin paddles for flap monitoring, eleven free vertical myocutaneous rectus abdominis (VRAM) flaps, and three free transverse myocutaneous rectus abdominis (TRAM) flaps were transferred. Indications for defect reconstruction were as follows: wound infection and chronic wounds with or without osteomyelitis ($n = 16$; 47%), malignant neoplasms ($n = 8$; 24%), trauma ($n = 8$; 24%), and burn injury ($n = 2$; 6%). The lower extremity was the most common recipient-site ($n = 22$; 65%), followed by the trunk ($n = 6$; 18%), upper extremity ($n = 4$; 12%), and head and neck ($n = 2$; 6%). Seven patients had previously undergone free ($n = 4$; 12%) and pedicled tissue transfer ($n = 3$; 9%) with consecutive partial or total flap loss. Three patients (9%) underwent simultaneous treatment of accompanying fractures of the ankle, tibial shaft, and olecranon, respectively. The most prevalent chronic conditions were arterial hypertension ($n = 28$; 82%) and diabetes mellitus ($n = 12$; 35%), followed by peripheral artery disease (PAD, $n = 11$; 32%), coronary heart disease ($n = 9$; 26%), and renal insufficiency ($n = 6$; 18%). Five patients (15%) suffered from both diabetes mellitus and PAD. A detailed summary is given in Table 1. Retrospective chart review was performed for patient demographics, individual risk factors, intraoperative details, surgical and medical complications, hospitalization, as well as outcome and mortality. Follow-up was established from the date of surgery to the last clinical visit at our outpatient clinic for all patients. The incidence of complications and their management as well as reconstructive long-term results and patient satisfaction were analyzed. During all follow-up examinations, the abdominal wall was meticulously examined for any signs of weakness or herniation, and patients were asked about any discomfort of the abdominal region.

Methods

Free flap raising was performed according to standard principles. All operative stages were performed with the patient in supine position allowing simultaneous preparation of the donor- and recipient-site. Management of accompanying fractures was performed first, if required. The anterior rectus sheath was always primarily closed using the partially absorbable Vypro II mesh in inlay technique fixed with Prolene 2-0 running sutures and an additional PDS 1-0 running fixation suture in all cases. Patients with percutaneous transluminal angioplasty (PTA) received dual

Table 1 Patient- and operation-related characteristics (BMI = body mass index, OT = operative time, PLOHS/LOHS = postoperative/overall length of hospital stay, N/IDDM = non/insulin-dependent diabetes mellitus, BMI = body mass index).

Number of patients and flaps	34
Gender distribution [female/male]	11/23
Mean age [years] ± SD (range)	68.5 ± 13.7 (42 - 89)
Mean ASA class ± SD (range)	2.7 ± 0.6 (2 - 4)
Median ASA class (range)	3 (2 - 4)
Mean BMI [kg/m^2] ± SD	28.5 ± 6.1
Mean OT [min] ± SD (range)	325 ± 75 (180 - 512)
Mean LOHS [days] ± SD (range)	45 ± 23 (15 - 115)
Mean PLOHS [days] ± SD (range)	30 ± 18 (10 - 92)
Arterial Hypertension (HTN)	28 (82%)
Diabetes Mellitus (DM)	12 (35%)
NIDDM	7 (21%)
IDDM	5 (15%)
Peripheral Artery Disease (PAD)	11 (32%)
Coronary Heart Disease (CHD)	9 (26%)
Adiposity (BMI > 30 kg/m^2)	8 (24%)
Atrial fibrillation	7 (21%)
Renal insufficiency	6 (18%)
Active Smoker at Time of Surgery	4 (12%)

platelet inhibition with aspirin 100 mg and clopidogrel 75 mg for at least five days following the intervention. Clopidogrel was then paused five days before flap surgery and continued on postoperative day five after drain removal for 3–12 months. Intraoperatively, anticoagulation therapy consisted of 500–1000 units of unfractionated heparin administered as an intravenous bolus shortly before opening the arterial anastomosis or, in case of simultaneous vascular reconstruction via an arteriovenous loop, an intravenous bolus of 2000–3000 units of unfractionated heparin before clamping of the source vessels. Depending on comorbidities, patients received low molecular weight heparin either in prophylactic or therapeutic doses postoperatively. Furthermore, all patients with perioperative vascular surgery received aspirin 100 mg as routine medication.

The ASA physical status classification system was used to assess comorbidities.[6-8] Peri- and postoperative complications were divided into surgical and medical aspects. Surgical complications were defined as operation-related complications of either the donor- or recipient-site. The primary surgical complications studied were “re-exploration,” “partial flap loss,” and “total flap loss” within 30 days after flap surgery, particularly microvascular complications. Medical complications were defined as all other postoperative systemic complications requiring further therapy. Mean operative time (OT) was grouped into procedures lasting less than and greater or equal to the 75th percentile. Likewise, total flap size was categorized into surface areas measuring less than and greater or equal to the 75th percentile. Mean patient age and mean ASA status were also dichotomized into two groups, younger than the 75th percentile or older and classes 1-2 and 3-4, respectively.

Table 2 Distribution of ASA status (mean 2.7, SD ± 0.6) and medical complications.

ASA class	Number of patients	Percentage	Medical Complications	ICU
1	0	0%	0 (0%)	0 (0%)
2	11	32%	2 (18%)	2 (18%)
3	21	62%	9 (43%)	13 (62%)
4	2	6%	2 (100%)	2 (100%)
5	0	0%	0 (0%)	0 (0%)
Total	34	100	13 (38%)	17 (50%)

Statistical analysis

Univariate analysis was performed to compare patients with and without flap failure, re-exploration, surgical and medical complications, intermediate care (IMC) or intensive care unit (ICU) admission, and prolonged length of hospital stay (LOHS) for each risk factor. The unpaired two-sided *t*-test, two-sided Mann–Whitney test, and two-sided Fisher’s exact test were used to assess the differences of means for continuous, categorical, and dichotomous variables between groups. For each risk factor, the odds ratio and its 95% confidence interval were derived for all statistically significant differences. All risk factors with $p < 0.2$ were entered into the binary logistic regression model to identify significant predictors for complication. All statistical analyses were performed using GraphPad Prism 7.0 (GraphPad Software, Inc., San Diego, CA) and SPSS Version 20.0 (IBM, Inc., Armonk, NY).

Results

Incidence of free flap failure, re-exploration, and complications

Data acquisition and follow-up were established for each of the included 34 patients included in the study. The mean OT was 325 ± 75 min and ranged from 180 to 512 min. The distribution of ASA status was 2 in 11 patients, 3 in 21 patients, and 4 in 2 patients. There were no ASA 1 or 5 class patients (Table 2). The mean follow-up time was 17.7 ± 8.8 months (range: 2 to 51 months; median: 15 months). Twenty patients (59%) underwent soft tissue reconstruction and perioperative vascular interventions, of which 16 cases (44%) were extremity reconstruction (1 upper, 15 lower). The procedures were in detail: preoperative bypass or arteriovenous loop surgery ($n = 9$), preoperative PTA or thromboendarterectomy ($n = 5$), or simultaneous vascular reconstruction and microvascular free flap transfer ($n = 7$). Examples are shown in Figures 1-3 and a detailed overview is given in Table 3. Indications for vascular interventions included: (1) Paucity of recipient vessels due to diabetes mellitus or PAD; (2) avoidance of vascular anastomosis in the area of traumatic injury, previous infection, or percutaneous irradiation, and (3) distances between the anastomotic site and distal defect border greater than 30 cm. Postoperative complications are summarized in Table 4. The incidence of surgical and medical complications was 32%

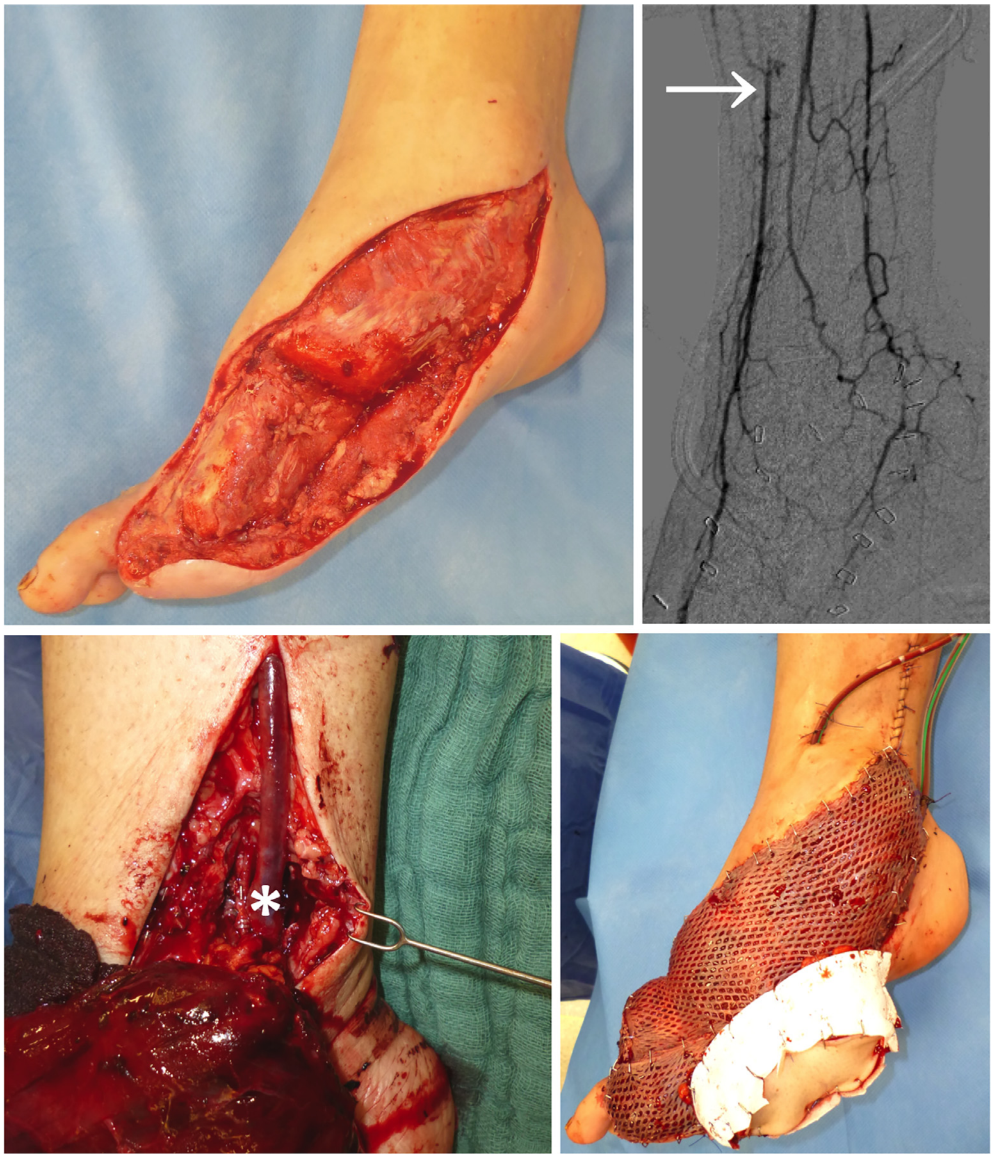

Figure 1 Example of a deep and multilayered lower extremity wound in a diabetic foot: The patient developed a pyogenic infection of the right foot after minor injury, which required radical surgical debridement. Defect coverage of the exposed metatarsal and tarsal structures was achieved by a free RAM flap combined with simultaneous bypass grafting for the anterior tibial artery occlusion (→) using the contralateral greater saphenous vein (*).

and 38%, respectively. In detail, 11 patients experienced a total of 22 surgical complications, of which 15 were considered major (requiring additional surgery) and seven were considered minor (conservative treatment). Major surgical complications were further divided into recipient- ($n = 9$) and donor-site ($n = 6$) complications: nine patients (27%) required free flap re-exploration for hematoma evacuation ($n = 5$) or local infection ($n = 4$) and six patients (18%) underwent revisional surgery of the donor-site due to wound dehiscence ($n = 4$), hematoma formation ($n = 1$), or local infection ($n = 1$). There were no postoperative microvascular complications (arterial or venous thrombosis). All donor-sites healed satisfactorily. Figure 4 shows an exemplary stable long-term outcome six months after free VRAM transfer for the reconstruction of the lower extremity following neoadjuvant isolated lower limb perfusion and compartment resection of a myxofibrosarcoma in an 86-year-old female patient. There was no case of weakness or herniation of the abdominal wall. Furthermore, there was no total flap loss. Partial flap loss occurred in one patient (3%), who required further free flap surgery. There was one case of transtibial amputation 12 months after lower extremity reconstruction due to recurrent osteomyelitis in the context of diabetic foot syndrome. In all other cases, the transferred flaps yielded mechanically stable soft tissue covering and an overall satisfactory cosmetic appearance. A total of 18 postoperative medical complications were seen in 13 patients (38%), in detail comprising altered mental status or postoperative delirium ($n = 6$; 18%), atelectasis or pneumonia with respiratory insufficiency ($n = 4$; 12%), congestive heart failure ($n = 3$; 9%), cardiovascular instability with severe hypotension ($n = 2$, 6%), paralytic ileus ($n = 1$; 3%),

Figure 2 This 78-year-old patient suffered from diabetic foot syndrome and end-stage PAD. An angiogram revealed complete occlusion of both the anterior and posterior tibial arteries and high grade stenosis of the remaining fibular artery (→). Lower limb salvage was achieved by a free RAM flap that was anastomosed to the popliteal artery (P3 segment) via a long vein graft (contralateral greater saphenous vein).

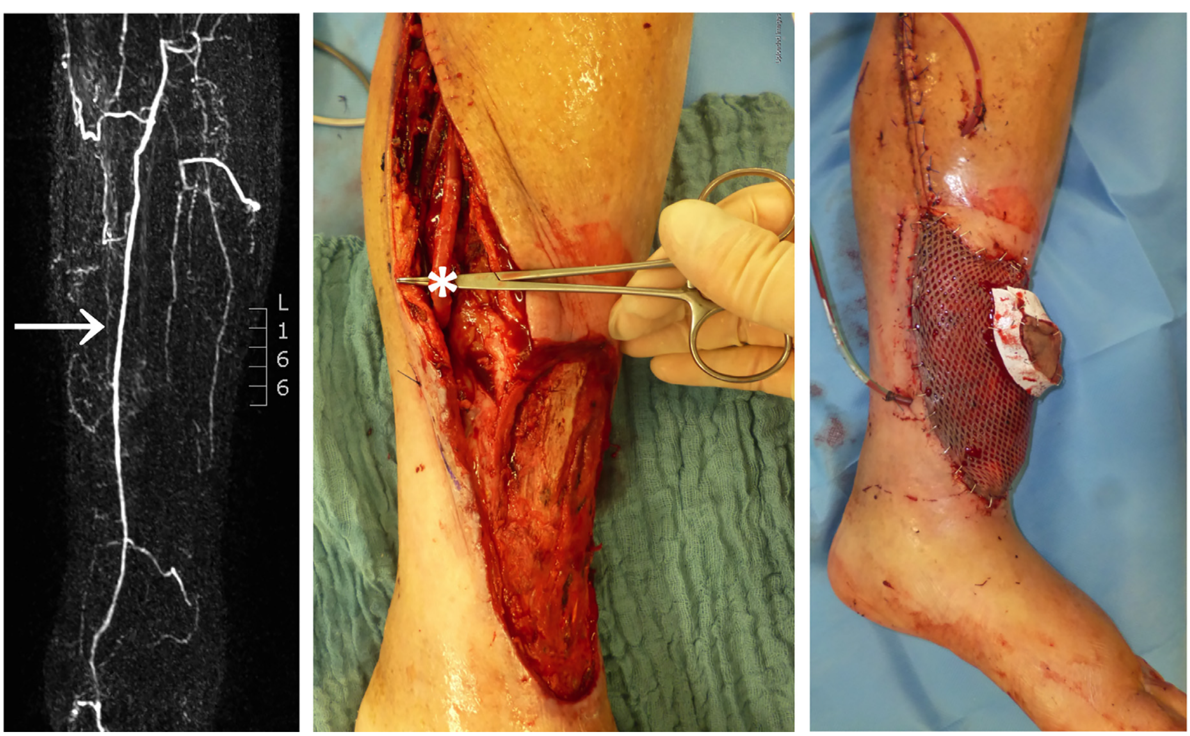

Figure 3 Example of critical limb ischemia: only the posterior tibial artery showed some residual contrastation (→). Lower limb salvage was achieved by two-stage vascular and soft-tissue reconstruction. An arteriovenous Loop was created between the popliteal vessels by interposition of a contralateral greater saphenous vein graft (*). A free RAM flap was then anastomosed to both loop vessels ten days later.

Table 3 Summary of patients with perioperative vascular interventions (Loc = defect localization, Preop = preoperative, Introp = intraoperative, VS = vascular surgery, Anast = anastomosis, OT = operative time in minutes, WI/IW = wound infection/impaired wound healing, Mal/Irr = resection/irradiation of malignant neoplasms, LE = lower extremity, UE = upper extremity, BPG = bypass graft, PTA = percutaneous transluminal angioplasty, TEA = thromboendarterectomy, AVL = arteriovenous loop, E-S = end-to-side, E-E = end-to-end, ATA = anterior tibial artery, ATP = posterior tibial artery, BA = brachial artery, CV = cephalic vein, DPA = dorsalis pedis artery, FA = fibular artery, GSV = greater saphenous vein, PA = popliteal artery, RIMA = right internal mammary artery, SA = subclavian artery, SFA = superficial femoral artery, fem-fem = femoro-femoral, fem-pop = femoro-popliteal, pop-cru = popliteo-crural, cru-ped = cruro-pedal).

	Age	ASA	Etiology	Loc	Flap	Preop VS	Intraop VS	Graft Anast	Flap Anast	OT
1	58	3	WI/IW	Trunk	RAM	-	AVL (CV)	E-S to SA	E-E to AVL	325
2	71	3	Mal/Irr	Trunk	TRAM	-	AVL (GSV)	E-S to SFA	E-E to AVL	512
3	79	3	WI/IW	Trunk	VRAM	-	AVL (CV)	E-E to RIMA	E-E to AVL	450
4	47	2	WI/IW	LE	RAM	PTA (ATA,ATP)	BPG (GSV)	E-S to PA	E-E to BPG	352
5	78	3	WI/IW	LE	VRAM	BPG (fem-pop)	BPG (GSV)	E-S to PA	E-E to BPG	315
6	66	4	WI/IW	LE	RAM	TEA (SFA) BPG (pop-cru)	-	E-S to PTA	E-S to BPG	389
7	54	3	WI/IW	LE	RAM	BPG (fem-pop)	-	E-S to PA	E-S to ATA	348
8	76	3	WI/IW	Trunk	VRAM	-	AVL (CV)	E-S to SA	E-E to AVL	430
9	79	3	Trauma	LE	RAM	-	BPG (GSV)	E-S to PA	E-E to BPG	325
10	82	3	Trauma	LE	RAM	BPG (pop-cru)	-	E-S to PTA	E-S to BPG	317
11	78	3	WI/IW	LE	VRAM	PTA (SFA,ATA,AF) BPG (cru-ped)	-	E-S to DPA	E-S to BPG	300
12	57	3	Trauma	LE	RAM	BPG (fem-fem)	-	E-S to SFA	E-S to ATA	364
13	49	2	Trauma	UE	RAM	-	AVL (GSV)	E-S to BA	E-E to AVL	395
14	52	2	Trauma	LE	RAM	-	AVL (GSV)	E-S to SFA	E-E to AVL	412
15	84	4	WI/IW	LE	RAM	PTA (PA,ATP,FA) AVL (GSV)	-	E-S to PA	E-E to AVL	300
16	61	2	WI/IW	LE	RAM	AVL (GSV)	-	E-S to SFA	E-E to AVL	206
17	84	3	Mal/Irr	LE	RAM	-	BPG (GSV)	E-S to SFA	E-E to BPG	324
18	76	2	Trauma, WI/IW	LE	VRAM	BPG (pop-cru)	-	E-S to FA	E-S to BPG	305
19	77	3	WI/IW	LE	VRAM	PTA (ATA,ATP)	-	-	E-S to ATP	381
20	75	3	Trauma, WI/IW	LE	RAM	-	BPG (GSV)	E-S to PA	E-E to BPG	399

Table 4 Summary of surgical and medical complications (AMS = Altered Mental Status; Multiple complications per patient).

Surgical Complications	n (%)	Medical Complications	n (%)
Recipient Site	12 (35%)	Cognitive Impairment (AMS/Delirium)	6 (18%)
Major	*9 (27%)*	Respiratory Impairment	4 (12%)
Hematoma Formation	5 (15%)	Congestive Heart Failure	3 (9%)
Wound Infection	4 (12%)	Cardiovascular Instability	2 (6%)
Minor	*3 (9%)*	Septic Shock	1 (3%)
Donor Site	10 (29%)	Paralytic Ileus	1 (3%)
Major	*6 (18%)*	Deaths	1 (3%)
Wound Dehiscence	*4 (12%)*		
Hematoma Formation	1 (3%)		
Wound Infection	1 (3%)		
Minor	4 (12%)		

and septic shock ($n = 1$; 3%). Three patients experienced multiple complications (9%). One patient (ASA 3) died at postoperative day 30 because of the progressive respiratory failure. The corresponding mortality rate was 3%. The postoperative medical complication rates were 18% for ASA class II patients ($n = 11$), 43% for ASA class III patients ($n = 21$), and 100% for ASA class IV patients ($n = 2$). Seventeen patients (50%) were admitted to the ICU for postoperative monitoring and critical care over a mean length of 8 ± 12 days. ASA status was a significant predictor for the necessity of postoperative critical care monitoring ($p = 0.03$), as shown in Figure 5. Finally, reconstruction was successful in 31 out of 34 patients, corresponding to a success rate of 91%, with mechanically stable soft-tissue covering and an overall satisfactory cosmetic appearance at follow-up.

Comparison of risk factors between patient groups

There was no statistical difference in re-exploration rates between both the dichotomized ASA and age groups. Patients with medical complications had significantly higher ASA scores (3.0 ± 0.1 vs. 2.6 ± 0.1, $p = 0.007$). No significant differences were found for all other risk factors. Figure 5 visualizes the relationship between ASA class and intensive care.

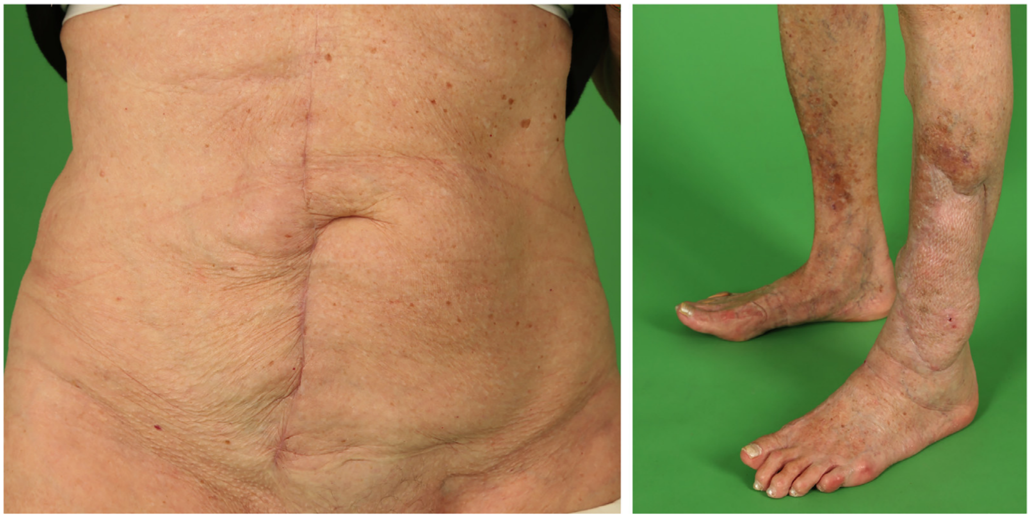

Figure 4 Example of a stable long-term outcome six months after free VRAM transfer for reconstruction of the lower extremity following neoadjuvant isolated lower limb perfusion and compartment resection of a myxofibrosarcoma in an 86-year-old female patient.

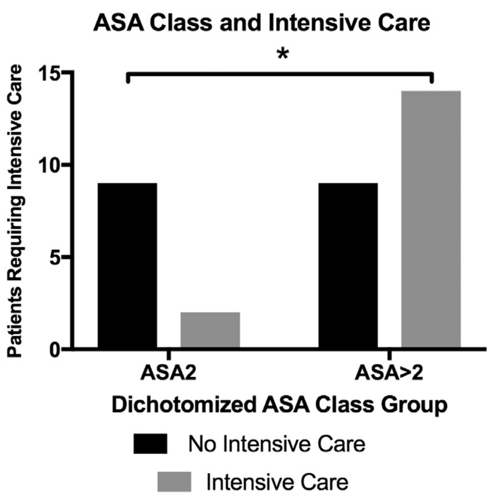

Figure 5 Univariate analysis of ICU admission according to ASA class: The relative risk of ASA 3 or 4 patients require postoperative ICU monitoring was 7 times the risk of ASA 2 patients (OR = 7; 1.38 35.96 95% CI; $p = 0.030$).

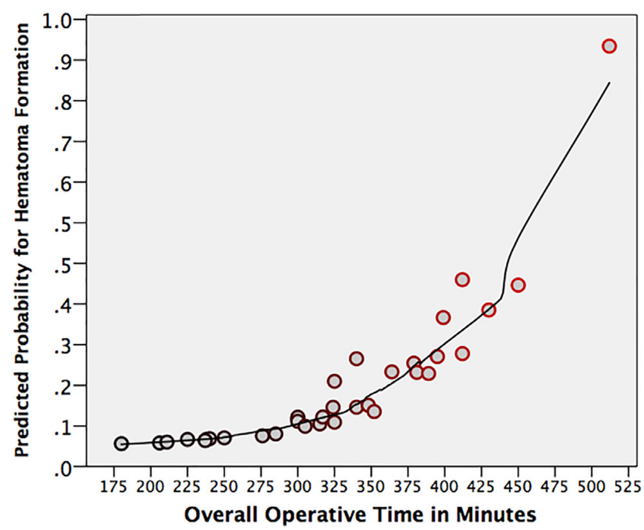

Figure 6 Binary logistic regression revealed that operative time (OT) was an independent risk factor predicting re-exploration for bleeding and hematoma: in this significant regression model (Chi-Square = 6.859, $p = 0.009$, $n = 34$) each additional minute of OT will increase the relative risk of requiring hematoma drainage by 3.7%.

Risk of re-exploration and complications

The following risk factors with $p < 0.2$ from the univariate analysis were entered into multivariate regression models for re-exploration, medical and surgical complications, ICU admission, and prolonged LOHS to identify predictors for complication: total flap size, ASA score, patient age, and total OT. Binary logistic regression revealed that prolonged OT was an independent risk factor for developing hematoma requiring surgical drainage ($p = 0.009$). Figure 6 shows the respective regression curve.

Discussion

Recent epidemiological studies report multimorbidity rates between 43% and 82% for those aged 65 years and older in Europe and the United States, with PAD and diabetes mellitus leading the way.[10,11] It is therefore mandatory that we critically review indications, applicability, and limitations of extensive reconstructive plastic surgery in this patient cohort. In 2000, Serletti et al. presented a study of 104 free flaps in 100 patients with a mean age of 72 years and identified two important trends: (1) Higher ASA classes correlated with the incidence of postoperative medical complications and (2) prolonged OT predicted surgical complications, mainly bleeding and hematoma.[8] These findings are in line with our work as we identified (1) ASA status as a significant predictor for the necessity of postoperative critical care and (2) prolonged OT as the only independent risk factor for developing postoperative hematoma requiring surgical revision. However, we operated on a considerably higher number of patients that underwent preoperative vascular surgery (32%), simultaneous vascular reconstruction and flap transfer (32%), or treatment of fractures (9%). These aspects may further increase the risk of postoperative bleeding or hematoma formation. With an overall reconstructive success rate of only 70%, Serletti and colleagues demanded for further improvement of therapeutic options in this "most challenging patient group".[8] The dilemma, however, begins when a defect cannot be reconstructed with reasonable efforts, such as local or pedicled flaps and free flap surgery becomes the only remaining reconstructive option in this patient group. In a study overlooking 58 free flaps in 54 patients with a mean age of 75 years, Verhelle and colleagues found that higher ASA classes and longer OT increased the risk for postoperative surgical and medical complications.[12] Similarly, patients with higher ASA status were at a significantly higher risk to require intensive care monitoring in our collective. To avoid complications, the investigators suggested to "keep the operative time as short as possible" and limit flap choice to "easily accessible flaps".[12] In contrast, Coskunfirat and colleagues could only identify higher ASA status but neither prolonged OT nor age as predictors for postoperative complication in the elderly after analysis of 102 free flaps in 94 patients with a mean age of 74 years.[9] However, 77% of their flaps were transplanted to the head and neck region, a recipient-site generally less affected by PAD and diabetes mellitus, as compared to the lower extremity. Contrary, in our study population, 12 patients suffered from diabetes mellitus (35%) and eleven from PAD (32%) – with five patients (15%) bearing both burdens. Twenty-two patients (65%) underwent lower extremity reconstruction, with most of them requiring perioperative vascular surgery. Furthermore, seven patients (21%) had previously undergone pedicle or free tissue transfer with consecutive partial or total flap loss. At this point, we want to emphasize that, when weighing major amputation versus extremity salvage, one must always bear in mind that amongst older patients, who often suffer from PAD and diabetes mellitus, major lower extremity amputation results in devastating five-year mortality rates between 71% and 80%.[13-16] Furthermore, impaired mobilization because of a lower tolerance of prosthesis in the elderly further aggravates this problem. Our group recently investigated the outcome of microvascular free flap reconstruction of lower extremity defects in patients older than 65 years and concluded that it can be performed safely with high success and manageable complication rates.[17] Pursuing the main objective of minimizing treatment time and complication rates to an absolute minimum through keeping the OTT as short as possible, we choose the easily accessible free RAM flap for this "most challenging patient group", although not considered a first-line flap due to its donor-site morbidity, because we think it has some advantages. Mainly, surgery is possible with the patient in supine position, which considerably reduces time-consuming patient positioning, and flap harvest is straight forward, which reduces OTT. Operation in supine position allows a two-team-approach with simultaneous preparation of the donor- and recipient-site: in the ideal case flap harvest, treatment of extremity fractures, and preparation of the recipient vessels can be performed simultaneously. Further advantages of the RAM flap are: highly vascularized soft-tissue, large caliber of donor vessels, good flap size and pedicle length, easy flap positioning, low donor-site morbidity, and good long-term functional and cosmetic results. Meland and colleagues reported an early series of 80 free RAM flaps focusing on the extent and degree of donor-site morbidity.[18] Rao and Baertsch published a successful series of 21 free RAM flaps for upper extremity reconstruction.[19] Horch and Stark highlighted the safety and reliability of the free RAM flap for emergency upper extremity reconstruction.[20] Musharafieh and colleagues reviewed 40 cases of free RAM flap lower extremity reconstruction with a successful reconstruction rate of 93%.[21] We agree with the investigators' conclusions that the free RAM flap offers some advantages, such as easy positioning, large donor vessels, highly vascularized soft-tissue, low donor-site morbidity, and good long-term functional and cosmetic results. Furthermore, we experienced that the free RAM flap is ideally suited for transfer in combination with vascular bypasses or arteriovenous loops because of the large diameter of the inferior epigastric vessels, the well-vascularized musculature, and the low intrinsic vascular resistance. In this particular field, Tukiainen and colleagues evaluated the long-term outcome of combined vascular reconstruction and microvascular free flap coverage of ischemic lower leg lesions in 79 patients.[22] The most common free flaps used were the latissimus dorsi ($n = 45$) and RAM ($n = 19$) flaps. They reported a 1- and 5-year leg salvage rate of 73% and 66%, respectively. Furthermore, male gender and ASA 4 status were associated with an increased risk of death.[22]

However, harvesting the RAM may result in abdominal wall weakness, abdominal bulging, and hernia. These adverse effects have been well-investigated in the field of breast reconstruction. Early studies showed that harvesting deep inferior epigastric perforator (DIEP) or muscle-sparing transverse rectus abdominis (MS-TRAM) flaps had significantly less donor-site morbidity than TRAM flaps.[23] Numerous studies have compared the incidence of donor-site morbidity in patients receiving TRAM or DIEP flaps. A systematic review by Sailon et al. revealed a trend toward decreased abdominal bulging with the DIEP flap.[24] A higher relative risk of hernia in TRAM flaps compared with DIEP flaps has further been reported.[23-27] Furthermore, older age was associated with an increased risk of hernia repair after abdominal flap breast reconstruction.[27] Further investigations of donor-site complications after abdominal flap breast reconstruction revealed significantly more cases of abdominal flap necrosis, umbilical necrosis, abdominal bulging, and hernia among smokers.[28] There were also significant more cases of abdominal flap necrosis amongst diabetic patients.[28] Boehmler et al. reviewed outcomes with various techniques of abdominal fascia closure after TRAM flap breast reconstruction.[29] Interestingly, there was no statistically significant difference in bulge formation or complication rates by age. They concluded that primary closure of the fascia, when feasible, resulted in the lowest rates of bulge formation and complications. Furthermore, primary closure in combination with a synthetic (polypropylene) mesh applied as an inlay graft, further reduced bulge formation and other complications.[29] In our patient cohort, the anterior rectus sheath was always primarily closed using the partially absorbable Vypro II mesh in inlay technique. However, the risk of donor-site-specific complications should be considered carefully in the context of patient comorbidities and age when selecting the RAM flap for microvascular reconstruction. We could achieve a successful reconstruction rate of 91% in our study population of 34 patients with a mean age of 74 years. There was no case of abdominal wall weakness or herniation so that we think that its main disadvantages can be accepted in this "most challenging patient group".

In summary, our study presents a consecutive series of patients with very high ASA scores to undergo reconstructive microsurgery yielding complete flap survival. With more than half of our patients (59%) undergoing extremity reconstruction, in most cases with additional perioperative vascular reconstruction, we clearly managed to review a challenging patient cohort on the edge of technical feasibility. We would like to emphasize that neither advanced age, nor higher ASA status compromised the surgical or medical outcome of soft-tissue reconstruction in our series. In accordance with previous studies, the main findings of our study include an increased incidence of surgical complications with prolonged OT.[8,9,12] However, this should be interpreted with respect to the following limitations: prolonged OT may be because of combined procedures like treatment of accompanying fractures or simultaneous vascular surgery resulting in additional microvascular anastomoses. These may also increase the risk for secondary bleeding or postoperative hematoma formation, partly due to a more aggressive anticoagulation therapy. Nonetheless, a relationship between prolonged OTT and higher complication rate is not surprising and has been reported by several other groups.[3,30,31] In our study, the mean OT of 325 $\pm$ 75 min is, however, considerably shorter compared to similar studies.[3,8,9] As well as previous literature on the matter, our findings underline that overall OTT should be kept as short as possible by complying with the following principles: choosing easily accessible and reliable flaps with large donor vessels and long vascular pedicles, achieving preoperative interdisciplinary, particularly vascular, optimization, and realizing a timely multi-team-approach. When these guidelines are kept in mind, even the most challenging patient cohorts can be offered successful microvascular reconstruction. Following these principles, the free RAM flap turned out to be a reliable and efficient option. However, we want to emphasize that our intention is not to praise the free RAM flap as the flap of choice for multimorbid elderly patients. Rather, we want to share our experience with the free RAM flap, which has proved as a suitable option with some advantages. Additionally, former studies and our single-center experience have shown that its donor-site morbidity can be reduced when primary closure of the anterior rectus sheet is combined with a synthetic mesh inlay graft.

Our study has its limitations, however. It represents our single-center experience with the free RAM flap as a reliable and efficient reconstructive option in multimorbid elderly patients. The study is limited by the retrospective character of data analysis. Furthermore, our study collective is small, especially when attempting to statistically analyze infrequent events like donor-site complications, flap loss, and reconstructive failure. Another weak point is that the flap harvest time, as an important determinant to underline our preference for the RAM flap, could not be extracted from the OTT. A more detailed analysis of multimorbid elderly patients undergoing combined extremity reconstruction and limb revascularization is therefore needed.

Conclusion

With regard to risk minimization, the free RAM flap has proven as a reliable and efficient tool in the armamentarium of reconstructive microvascular surgeons with some advantages in the treatment of multimorbid patients older than 65 years otherwise jeopardizing microsurgical endeavors, particularly in those suffering from end-stage PAD requiring lower limb salvage. This strategy helped us to expand the limits of microsurgical defect reconstruction and limb salvage in critically ill, multimorbid, and elderly patients. Its advantages outweighed the disadvantages in our study but, however, the risk of donor-site complications should be kept in mind. Finally, donor-site morbidity can be reduced when primary closure of the anterior rectus sheet is combined with a synthetic mesh inlay graft.

Conflict of interest statement

None of the authors received any funds or has any financial interests to disclose.

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