Risk Factors and Blood Flow in the Free Transverse Rectus Abdominis (TRAM) Flap

Smoking and High Flap Weight Impair the Free TRAM Flap Microcirculation

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Abstract: Mastectomy patients may have significant psychologic-related problems. Breast reconstruction provides in these cases substantial benefits in restoring body image and health-related quality of live. Autologous free tissue transfer is the treatment of choice due to excellent outcome. The purpose of this study was to elucidate the effect of the risk factors on the microcirculation and clinical outcome.

In this prospective study, 21 patients with a free transverse rectus abdominis (TRAM) flap breast reconstruction were included. Patient demographics and flap characteristics were recorded. Blood flow was recorded in the central part (zone I) and the distal part (zone IV) of the flap with the laser Doppler flowmetry (LDF; Perimed).

In this study, increased flap complications were seen in smokers when compared with nonsmokers ($P < 0.000$). LDF was higher in the older patient population ($P = 0.008$) in zone IV. Smoking, especially in combination with a high flap weight (HFW), revealed lower blood-flow values ($P = 0.020$) in zone IV. Other possible influencing risk factors such as a HFW and history of radio- and chemotherapy did not alter the microcirculation. Patients with smoking and a HFW did also show decreased blood flow but also more severe flap complications.

Smoking, especially in patients with a HFW, impairs the free TRAM flap microcirculation in zone IV. In our opinion, these patients can still be included for reconstruction. However, extra care has to be taken during flap design to minimize disturbed wound healing.

Key Words: microcirculation, laser Doppler flowmetry, TRAM flap, risk factors, smoking, obesity

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Breast cancer is the most common cancer in women in the world and the second most common cancer in Western societies.[1] Breast reconstruction is considered a valuable tool in treatment of breast cancer. Restoring health-related quality of life, body image, and cosmetic outcome are important issues in the treatment of breast cancer.[2–5] The use of autologous tissue is preferred due to more natural-appearing reconstructed breasts. Furthermore, it avoids the complications inherent in the use of implants, such as infection and capsular contracture. Due to high success rates, reconstructive surgeons include patients with various risk factors. Reports regarding the risk factors on the clinical outcome are not unambiguous. The purpose of this study was to elucidate the effect of the risk factors on the microcirculation and clinical outcome.

The pedicled transverse rectus abdominis (TRAM) flap was first introduced and popularized by Hartrampf et al.[6] Although proven to be reliable, flap complications (FC) such as partial flap loss and fat necrosis (FN) occurred frequently as a result of folding, tunneling, and poor blood supply to the distal part of the flap.[7] Although several modifications have been made to increase flap perfusion and reduce donor site morbidity,[7–10] recent studies still report FC with these flaps (Table 1).[8,11–19] There is an inconsistent FC incidence report between these studies, which may be related to several confounding factors. First, patient demographics and prevalence of the risk factors were different and/or not reported. Second, whether or not zone IV was included in the reconstructed breast is not reported consistently (Table 1). Third, the size and zone location of the complications within the flap are not systematically reported in the literature. These confounding factors may be the reason for the wide range of FC (0%–37%) described in the literature (Table 1).

The risk factors described in the literature have been shown to be inconsistent as significant factors for FC (Table 2). Reus et al[20] suggested that smokers are at increased risk for FC not at the site of the anastomosis but at the flap interface with the wound. The effect of obesity is also controversial regarding complications. Obesity is considered to be a risk factor with the pedicled TRAM flap for donor-site morbidity.[12] Reports on obesity as a risk factor for FC have also been unambiguous (Table 2). At first it was believed that a

TABLE 1. Literature Overview of Flap Complication Incidence

	Year	Flap Type (N)	Flap Complications (%)	Inclusion of Zone IV
Ducic et al[13]	2005	Pedicled TRAM (224)	PFL (9.8), FN (17.9), DWH (6.7)	NR
Scheer et al[19]	2006	DIEP flap (84), free TRAM flap (46)	PFL (1.3), FN (42.9) PFL (6.5), FN (8.7)	NR
Padubidri et al[18]	2001	Pedicled TRAM (198)	PFL (5.0), FN (10.6)	NR
Gill et al[14]	2004	DIEP (758)	PFL (2.5), FN (10.6)	Excised
Blondeel et al[8]	1999	DIEP (100)*	PFL (7.0), FN (6.0)	Variable inclusion
Kroll[7]	2000	DIEP flap I (8)†	PFL (37.5), FN (62.5)	Included
		DIEP flap II (23)†	PFL (8.7), FN (17.4)	Excised
		Free TRAM flap (279)	PFL (2.2), FN (12.9)	NR
Banic et al[11]	1995	Free TRAM flap (123)	PFL (6.6), FN (8)	Included
Cheng et al[22]	2006	DIEP (74)	PFL (2.7), FN (4.1)	Included
Nahabedian et al[17]	2002	DIEP flap (17)	PFL (0.0), FN (11.7)	NR
		Free TRAM flap (118)	PFL (0.0), FN (11.9)	
Knight et al[15]	2006	Free TRAM flap (76)	PFL (1.0), FN (13.7)	NR

DWH indicates delayed wound healing; NR, not reported.
*In the latter part of the study, zone IV was systematically discarded.
†In DIEP I, patients had the same selection criteria as free TRAM flap patients. In DIEP II, patients were selected to avoid risk factors and less then 70% of the abdominal flap was used in the reconstruction.

TABLE 2. Significant Risk Factors for Flap Complications in Literature (*P* Values)

	Flap	Smoking	Obesity	CHTH	RTx*	Age	HFW
Gill et al[14]	DIEP	S	NS	NS	S*	NS	NS
Nahabedian et al[17]	Free TRAM	NS	S	NA	NA	NA	NA
	DIEP	NS	S	NA	NA	NA	NA
Ducic et al[13]	Ped. TRAM	S†	S	NS	NS	NA	NA
Banic et al[11]	Free TRAM	NS	NS	NS	NS	NA	NA
Chang et al[12,35]	Free TRAM	NS	S‡	NA	NA	NA	NA
Selber et al[38]	Free TRAM	S	S§	NS	NS	NA	NA
Tran et al[39]	Ped. TRAM	NA	NA	NA	S*	NA	NA
Metha et al[40]	Ped. TRAM	NA	NA	NA	NS	NA	NA
Javaid et al[41]	Various‖	NA	NA	NA	S*	NA	NA

HFW indicates high flap weight; HT, hypertension; NA, not available; NS, not significant; S, significant; ped TRAM, pedicled TRAM flap; CHTH chemotherapy; RTx, postreconstructive irradiation.
*Postreconstructive irradiation.
†Significant for overall flap complications, not for just PFL or fN.
‡Significance in overall flap complications; no significance was found for PFL.
§Significant increase in mastectomy skin flaps necrosis.
‖Various types of free flaps.

large and heavy abdominal flap may stretch and attenuate the perforators, thereby compromising the blood flow to the flap.[21] Recently, studies reported large flaps (zones I–IV) using the perforator technique, with similar complication rates.[22,23]

In a previous study (submitted), we have shown in the free TRAM flap a delayed increase of blood flow in zone IV compared with zone I. In addition, a delayed increase of microcirculatory blood flow was associated with FC. Our hypothesis is that some risk factors such as smoking and high flap weight may cause insufficient increase of blood flow in zone IV during the acclimatization period. The purpose of this study was to analyze the effect of various patient and flap characteristics on the free TRAM microcirculation and clinical outcome.

PATIENTS AND METHODS

We prospectively evaluated 21 patients in this clinical study. The institutional ethical committee of the Maastricht University Hospital approved the study protocol. Written informed consent was obtained from all patients. Exclusion criteria were a lower vertical laparotomy scar and a disproportional abdominal mass compared with the volume needed for breast reconstruction. These patients were excluded because the blood-flow-measurement location was expected to be discarded (medial border of zone IV). In addition, only patients with a secondary breast reconstruction with no surplus of skin at the recipient site were included. These inclusion criteria resulted in preservation of the measurement sites in zone I and zone IV in the reconstructed breast. As a result, all patients who were included in the study had zones I-III and zone IV to a variable degree, depending on the volume needed for reconstruction (Fig. 1). Flap blood-flow zones were named in accordance to our own clinical experience and recent literature, with zones I and II on the ipsilateral side of donor vessels and III and IV on the contralateral side.[24]

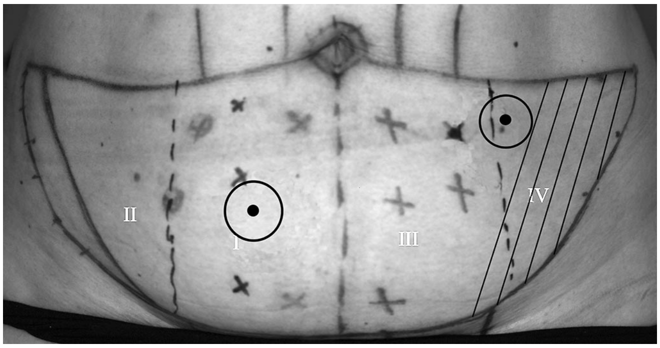

FIGURE 1. Zone classification and LDF measurement sites. I–IV, Blood flow zones. The black point within the circle represents the laser Doppler flowmetry sites. Ipsilateral to the vascular pedicle, the LDF probe holder in zone I is sutured between the medial and lateral row of the perforators, whereas the second holder is sutured at the medial border in zone IV. The shaded area represents the part of the flap (zones III and IV), which was discarded to a variable degree, depending on the volume needed for reconstruction.

Operations were performed by experienced plastic surgeons. The muscle-sparing free TRAM flap was used in all patients for breast reconstruction; with this procedure, a small medial part of the rectus abdominis was harvested, along with several lateral (2–3) and medial (1–2) perforators.[25] In all patients, the internal mammary vessels were used for the anastomosis.

Factors used for analysis included patients' age and obesity, defined in body mass index (BMI) subgroups of <25, 25–30, and >30. History of radiotherapy, chemotherapy, and tobacco use (defined as active smoking on preoperative day) was recorded. Flap weight used for reconstruction (FW) and percentage of the original abdominal flap used for reconstruction was recorded (FWU). FWU was recorded because it represents the inclusion of the zones (especially zone IV) of the TRAM flap. Inclusion of zone IV is also considered as a risk factor. The duration of ischemia period during the anastomosis was recorded. In addition, influencing factors on blood flow such as hemodynamics and room, patient, and flap temperature were recorded for analysis. Perioperative fluid management and hematocrit levels were analyzed due to the possible effect of hemodilution on blood viscosity and blood flow. FC used for analysis in this study were photographed and percentage of necrosis was calculated using planimetry. Partial flap loss was classified as minor when less then 3% skin loss occurred with or without its underlying subcutaneous tissue (m-PFL). Major partial flap loss was classified as major when more then 3% skin loss occurred with or without its underlying subcutaneous tissue (M-PFL), this group represented a more severely affected group which required surgical debridement and secondary wound closure in the operating theater. FN incidence was recorded at the outpatient clinic for up to 3 months after the surgery. FC represents the cumulative number of patients with ether PFL or FN.

Cutaneous microcirculatory blood flow was measured using the Periflux 5000 system (Perimed). This is a reliable noninvasive method for evaluating microcirculatory blood flow and has been described previously.[26–31] Blood flow is presented in arbitrary units. Laser Doppler flow (LDF) measurements were performed intermittently for 5 days simultaneously in zones I and IV with the Periflux 5000 system (Table 3). Room temperature was standardized during the first 24 hours of the study (OR and recovery). All measurements were performed at absolute rest and for a period of 3 minutes. Probe holders were sutured to the flap to ensure identical measurement sites during the study. The probe of zone I was placed between the lateral and medial row of perforators, whereas the second probe was placed at the medial border in zone IV (Fig. 1). LDF was first measured during surgery, with the flap on its pedicle. This was performed after the muscle-sparing TRAM flap was completely dissected and solely connected to the vascular pedicle. At this point, the entire flap is supplied by the deep inferior epigastric

TABLE 3. Materials and Methods: Measurement and Control Intervals

	0–24 Hours (Day 0)					
	Surgery	Recovery	Day +1	Day +2	Day +3	Day +4
Blood pressure	15 min	1 h	—	—	—	—
Heart rate	15 min	1 h	—	—	—	—
Temperature (P)	15 min	1 h	1 h	2 h	—	—
Temperature (F)	—	1 h	1 h	Every other hour	—	—
Temperature (E)	Controlled (21°C)	Controlled (21°C)	Not controlled	Not controlled	Not controlled	Not controlled
Standard controls*	—	1 h	1 h	2 h	4 h	6 h
Laser Doppler flowmetry	FOP, ischemia and 1 h after reperfusion†	At 2, 3, 4, and 5 h after reperfusion	3 times a day (at 8:00, 12:00, 5:00)‡	3 times a day (at 8:00, 12:00, 5:00)‡	3 times a day (at 8:00, 12:00, 5:00)‡	3 times a day (at 8:00, 12:00, 5:00)‡
Vasoactive medication	Similar use	Not used	Not used	Not used	Not used	Not used

E indicates environment; F, flap; P, patient.
*Standard controls include ultrasound Doppler of perforators within the flap, skin color, and capillary refill.
†Flap-on-pedicle (FOP) measurement is performed after flap is completely dissected and solely connected to the vascular pedicle. At this point, the entire flap is supplied by the DIE vessels, which lead to the categorization of the flap zone (I–IV).
‡Statistical analysis was performed with these separate measurements. In graphs, mean daily values are shown in order to facilitate the data overview.

vessels, which lead to the categorization of the flap zone (I–IV). A 10-minute interval was chosen to have a standard time elapse, with no manipulation of dissected the flap. This may lead to false high-blood-flow values. In our own experience and a recently performed study (submitted), this acclimatization period takes, however, much longer. A longer acclimatization period was not used, because it would increase the duration of the surgery and may negatively affect the outcome. After successful transplantation, LDF was hourly measured, starting 1 hour after completion of the anastomosis. From the first to the fourth postoperative day, LDF was measured 3 times a day (Table 3).

All data are presented as mean values ± SEM. The SPSS program was used for statistical analysis. LDF data with the TRAM flap on its vascular pedicle are shown separately. After the anastomosis, the LDF data measured are displayed hourly up to 5 hours after reperfusion, and daily mean values are shown up to 4 days after surgery. Repeated-measures ANOVA was used for analysis of all the repeated measurements. Mann-Whitney *U* test was used for analysis of the individual quantitative parameters. For nonparametric data containing more than 2 groups, the Kruskal-Wallis test was used for analysis. Fisher exact test was used for categorical data. A *P* value <0.05 (2-tailed) was considered statistically significant.

RESULTS

Patients and Flap Characteristics

Mean age at time of operation was 48.4 ± 1.8 (range, 27–59) years and mean QI was 26.7 ± 0.7 (range 22–35). Incidence of chemotherapy (17/21; 81%), radiotherapy (11/21; 52%), and smoking (7/21; 33%) was high (Table 4). After trimming of the abdominal flap, the mean FW used for breast reconstruction was 821 ± 59 (range, 374–1451) g. The weight of the used flap divided by the FWU was 821 ± 59/959 ± 81 g, which gives an average of 88% ± 3% (range, 64%–100%). One hundred percent of the flap was used for reconstruction in 8 cases (40%). Mean flap ischemia time was 52 ± 3 (range, 32–100) minutes (Table 5). The measurement location of both measurement sites remained in the reconstructed breast in all patients.

TABLE 4. Patient Demographics

	All Patients (N = 21)	No FC (n = 12)	FC (n = 9)	*P*	M-PFL (n = 6)	*P*
Smoking*	7 (33.3%)	1 (8.3%)	6 (66.7%)	0.016	6 (100%)	<0.000
Radiation*	11 (52.4%)	4 (33.3%)	7 (77.8%)	0.080	4 (66.7%)	0.635
Chemotherapy*	17 (81.0%)	8 (66.7%)	9 (100%)	0.104	6 (100%)	0.281
Obesity (kg/m²)*						
<25	5 (23.8%)	5 (41.7%)	0 (0%)	NP	0 (0%)	NP
25–29	13 (61.9%)	5 (41.7%)	8 (88.9%)	0.036†	4 (66.7%)	0.262†
≥30‡	3 (14.3%)	2 (16.7%)	1 (11.1%)	0.045§	2 (33.3%)	0.114§
Age (yrs)‖¶	48.4 ± 1.8 (27–59)	49.1 ± 2.7 (32–59)	47.9 ± 2.4 (27–58)	0.695	50.8 ± 2.0 (46–57)	0.510
Cutoff (≥55 yrs)*‡	7 (33.3%)	4 (33.3%)	3 (43%)	1.000	3 (43%)	1.000
Length of stay (nights)‖¶	5.1 ± 0.3 (3–8)	4.7 ± 0.2 (4–6)	5.6 ± 0.6 (3–8)	0.279	8.2 ± 0.6 (6–10)	0.104

FC indicates flap complications; m-PFl, major flap loss; NP, not possible.
*Statistical analysis was performed with the Fisher exact test.
†BMI of 25–30 compared to a BMI of <25.
‡Categorical data with cutoff points used for LDF analysis (Fisher exact test) are also shown.
§BMI of ≥25 compared to BMI <25.
‖Mann-Whitney *U* test (All *P* values are 2-tailed).
¶Mean ± SEM.

TABLE 5. Flap Characteristics (Means ± SD)

	All Patients (N = 21)	FC (n = 9)*	No FC (n = 12)*	*P*
FW (g)†	821 ± 59 (374–1451)	949 ± 82 (600–1451)	725 ± 73 (374–1216)	0.069
FW >800‡§	11 (52%)	7 (64%)	4 (36%)	0.080
FWU (%)†	88 ± 3 (64–100)	90 ± 3 (72–100)	86 ± 4 (64–100)	0.615
FWU >90%‡§	11 (52%)	5 (45%)	6 (55%)	1.000
Ischemia (min)†	52 ± 3 (32–100)	49 ± 4 (32–66)	54 ± 5 (38–100)	0.695
Ischemia >60‡§	7 (33%)	3 (43%)	4 (57%)	1.000

FW indicates flap weight used for breast reconstruction; FWU, percentage of abdominal flap weight used for reconstruction.
*The percentages in these columns represent the percentage of persons with the relevant risk factor.
†Mann-Whitney *U* test was used for statistical analysis.
‡Fisher exact test used. (All *P* values are 2-tailed.)
§Categorical data with cutoff points used for LDF analysis are also shown.

TABLE 6. Patient Characteristics With Flap Complications

	FC	Age	BMI	Smoker	Radiotherapy	Chemotherapy	FW (g)	FWU (%)	Ischemia (min)
1	M-PFL	47	25	Yes	Yes	Yes	829	94	65
2	m-PFL	59	30	No	Yes	Yes	1451	90	50
3	m-PFL	32	25	No	Yes	Yes	600	99	32
4	M-PFL	57	35	Yes	Yes	Yes	712	89	50
5	M-PFL	57	25	Yes	Yes	Yes	1048	100	48
6	M-PFL	50	25	Yes	No	Yes	919	88	66
7	M-PFL	48	27	Yes	Yes	Yes	869	72	61
8	m-PFL	46	26	No	Yes	Yes	1096	81	34
9	M-PFL	46	30	Yes	No	Yes	1021	100	37

BMI indicates body mass index (kg/m^2).
Patients who required extra surgery for debridement or secondary closure were all smokers. Radiotherapy and chemotherapy were administered in all patients at least 2 months before reconstruction.

Clinical Outcome

FC occurred in 9 patients (43%). Three of these patients had M-PFL <3%, which was treated conservatively. Six patients with M-PFL required surgical debridement in the operating theater (29%). Table 6 shows the individual data of these patients. Patients were planned ±3 months after the breast reconstruction to undergo the symmetrization procedure to achieve final esthetic result. Procedures then performed to achieve final satisfactory esthetic results were predominantly ptosis correction of the contralateral breast.

All FC occurred in zone IV, with the exception of 2 cases in which M-PFL occurred in zones III and IV. FC occurred at a higher rate in the patients with an active smoking history compared with nonsmokers ($P = 0.016$). In addition, M-PFL occurred only in active smokers ($P < 0.000$). FC was higher in obese patients. Age, chemotherapy, and radiotherapy did not affect the outcome. A high flap weight (>800 g) was not associated with FC ($P = 0.08$) or with M-PFL ($P = 0.149$) requiring surgical debridement. A high flap weight in combination with active smoking was more clearly associated with FC ($P = 0.008$) and patients with M-PFL ($P < 0.000$). Percentage of FWU (with >90%; parts of zone IV are included in the reconstructed breast) as a risk factor was not significantly higher in patients with FC or in patients with M-PFL. The duration of the ischemia period did not have any effect on outcome in this study (Table 5).

Hemodynamics and Temperatures

No significant differences were observed in hemodynamics when comparing patients with FC to those without FC. Room temperature was measured every 15 minutes during the first 24 hours after surgery and revealed no differences when comparing patients with the various risk factors to those without these risk factors. After reconstruction, the flaps with PFL seemed to have a lower flap temperature. This was, however, not significant (data not shown).

Laser Doppler Flowmetry Results

Analysis of blood-flow measurements with the flap on its pedicle (after an acclimatization period of 10 minutes) revealed no significant differences in zone I when comparing patients with or without the various factors studied. In zone IV, a lower blood flow was measured in flaps weighing over 800 g compared with flaps weighing less than 800 g (Fig. 2; $P = 0.012$).

Patients with FC demonstrated lower blood flow in zone IV; however, this was not significant (data not shown). Patients with M-PFL had a significantly lower blood flow in zone IV compared with patients who had either no FC or M-PFL (Fig. 3; $P = 0.040$).

LDF in zone I after reperfusion revealed no differences in the possible risk factors studied. In zone IV, several differences were observed. The factors that were not significant on blood flow of zone IV following reperfusion were

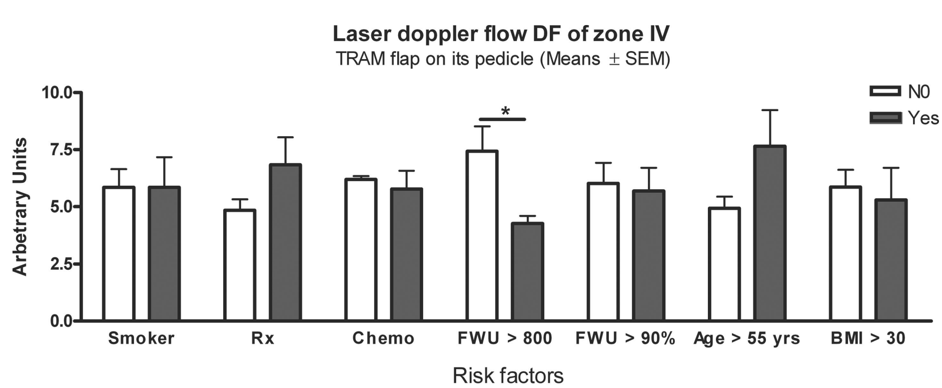

FIGURE 2. Laser Doppler flow of zone IV with flap on its pedicle. These blood-flow measurements were performed with the flap still on its vascular pedicle but completely dissected after a 10-minute acclimatization period. In zone I, risk factors were not found to influence blood flow significantly. In zone IV, a lower blood flow was measured in flaps weighing over 800 g compared with flaps weighing less than 800 g.

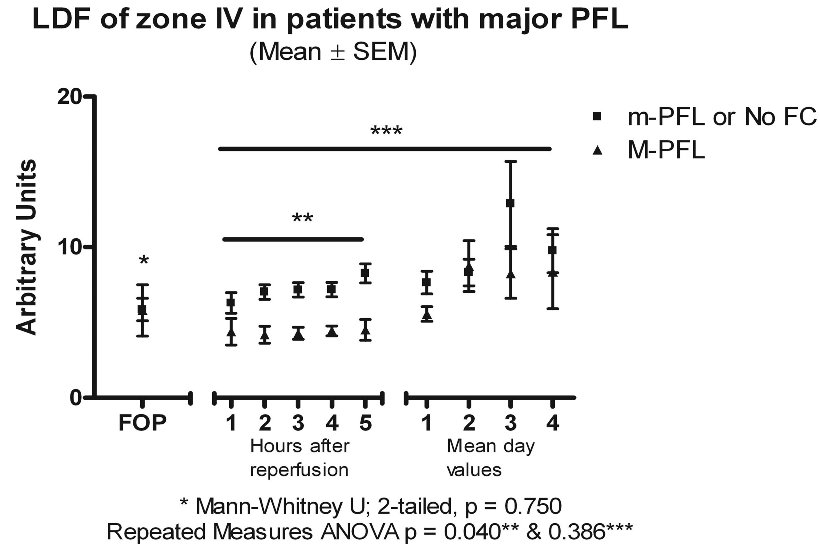

FIGURE 3. Lower blood flow following 1–5 hours after reperfusion precedes. FOP indicates flap on its pedicle measurement. In zone IV, a lower blood flow was measured during the first 5 hours after reperfusion in patients with M-PFL.

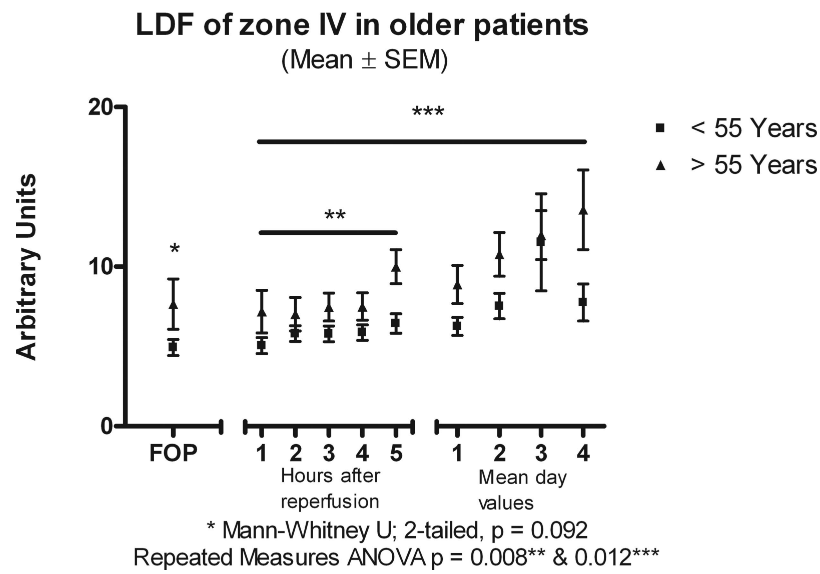

FIGURE 4. Laser Doppler flow of zone IV in older patients. FOP indicates flap on its pedicle measurement. A higher blood flow was measured in patients older than 55 years compared with younger patients. Age was not associated with flap complications.

radiotherapy, chemotherapy, flap weight, percentage of original abdominal flap, and ischemia time. Older patients (>55 years) showed higher blood flow in zone IV during the initial 5 hours after reperfusion compared with younger patients (Fig. 4; $P = 0.008$). No differences in LDF were observed in zone IV when comparing smokers to nonsmokers using the repeated-measures ANOVA. However, analysis with the Mann-Whitney *U* test for the measurements following reperfusion of zone IV revealed significant differences in 4 of the 5 hours measured (Fig. 5). Patients with a combination of both smoking and a high flap weight did show significantly lower blood flow during this 5-hour period compared with those patients without both risk factors (Fig. 6).

DISCUSSION

This clinical study shows that smoking, especially in patients with a high flap weight, leads to a reduction in microcirculatory blood flow of the free TRAM flap. Clinical outcome also revealed a significant increase in FC in smokers, as well as in obese patients.

Preoperative radiotherapy and chemotherapy did not alter the blood flow or the clinical outcome.

Age did not affect clinical outcome and was, interestingly, associated with an increased blood flow in zone IV after reperfusion. This increased blood flow lasted for the whole study period.

The age groups used in this study were not related to any of the other risk factors investigated in this study. Analysis of hemodynamics, which was monitored for the first 24 hours, revealed similar mean arterial pressure but an increased heart rate in older patients. Whether this increased heart rate may be the cause of increased blood flow remains to be seen.

Several studies focusing on free flap surgery in older patients have shown that age is not a significant risk factor and that age alone should not be considered as a risk factor.

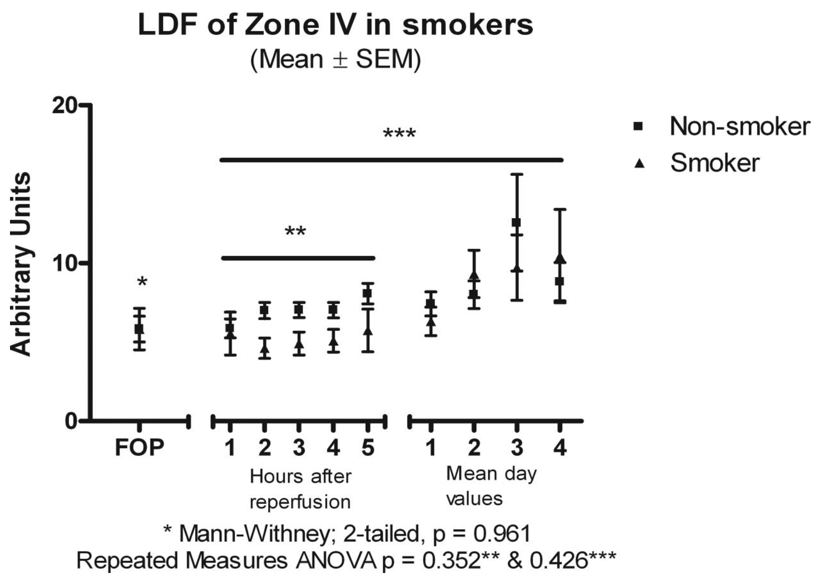

FIGURE 5. Laser Doppler flow of zone IV in smokers. FOP indicates flap on its pedicle measurement. Smokers were associated with a higher rate of M-PFL. A lower blood flow was observed in smokers compared with nonsmokers, although this was not significant. Using the Mann-Whitney *U* test for each separate measurement after reperfusion revealed significant lower blood flow in 4 of the 5 hours measured. Hours 2–5 after reperfusion had a *P* value lower than 0.05.

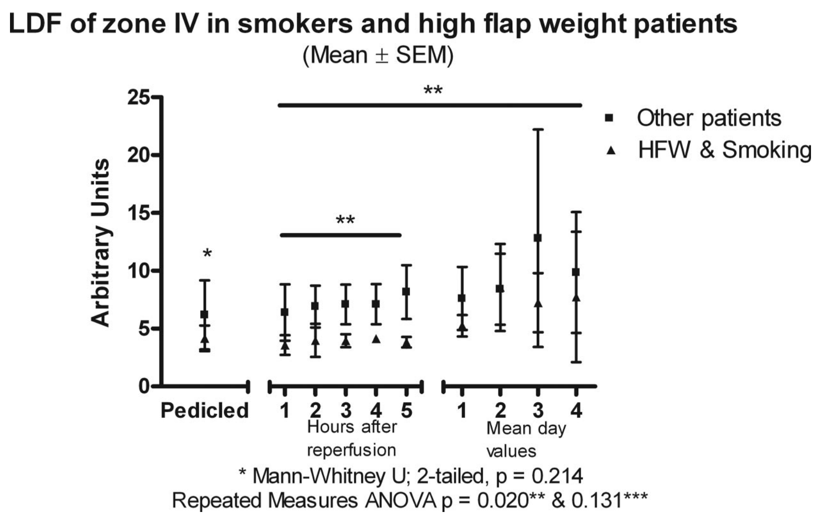

FIGURE 6. Laser Doppler flow of zone IV in patients with high flap weight and smoking. FOP indicates flap on its pedicle measurement. Patients with both smoking and a high flap weight were associated with a higher rate of M-PFL. A lower blood flow was observed in these patients compared with patients without both risk factors.

However, age did affect the rate of medical complications in some studies.[32,33] These medical complications are probably due to the status and comorbidity of other systemic diseases in these patients. Serletti et al[33] showed that physical status (ASA score) and duration of the operation are the significant predictors of postoperative morbidity. Therefore, with careful preoperative assessment and perioperative monitoring, high age alone should not be considered as a contraindication.

Smoking has long been known to be associated with disturbed wound-healing complications such as dehiscence and infection. The greatest risk for these complications is in wounds with wide surgical undermining such as abdominal flaps and facelifts.[34] These problems have also been reported in pedicled and free TRAM flap procedures.[35,36] In a previous study, we have shown that the viability of zone IV depends on the increase in blood flow to this region of the flap. Smoking leads to an impairment of microvascular function.[37] Therefore, smoking may impair the vasodilatory responses within the TRAM flap to zone IV during the flap acclimatization period. This theory is confirmed in this study by the reduced increase in blood flow which was observed in smokers. Reports in the literature show that these complications could be reduced by a cessation of smoking well in advance (3–4 weeks) of surgery.[35,36]

Although obesity was associated with an increase in FC, a high flap weight was not associated with a reduced blood flow. The percentage of the original abdominal flap used for reconstruction was also not associated with a reduced blood flow. However, patients with both smoking and a high flap weight compared with patients without both these risk factors showed even more clearly increased significance in the reduced blood flow in zone IV compared with smoking alone. Therefore, the inclusion of zone IV in especially these patients leads to a reduction in blood flow and increase in clinical complications. Compared with the recent series by Cheng et al[22] using the perforator surgical procedure with inclusion of zone IV, our study has a high number of FC. This may be explained by the difference in risk-factor prevalence compared with this study.

The clinical relevance of these findings is that zone IV can be safely included in patients with no risk factors. However, in smokers and obese patients the flap perfusion has to be critically assessed and trimmed accordingly. In these patients, complete removal of zones IV and III in combination with a contralateral reduction mammaplasty may be the safest option. In addition, we need to convince our patients with more persuasion to stop smoking well in advance of the surgery.

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