Comparison of Clinical Outcomes between Single- and Multiple-Perforator–Based Free Thoracodorsal Artery Perforator Flaps: Clinical Experience in 87 Patients

Mehmet Veli Karaaltin, M.D.
Adnan Erdem, M.D.
Samet Kuvat, M.D.
Günay Çavdar, M.D.
Hakan Kerem, M.D.
Semih Baghaki, M.D.
Halil İbrahim Canter, Ph.D., M.D.
Azimet Özdemir, M.D.

Istanbul, Bursa, Diyarbakir, and Manisa, Turkey

Background: Although thoracodorsal artery perforator flaps have not gained popularity in the reconstructive era, the results of recent studies regarding the vascularity of thoracodorsal artery perforator flaps are promising. In the present study, the authors aimed to determine the clinical outcomes of free multiple-perforator versus single-perforator thoracodorsal artery perforator flaps.
Methods: Eighty-seven patients with various defects underwent reconstruction with free thoracodorsal artery perforator flaps. The flap was used for upper extremity reconstruction in 43 patients (49.4 percent), for head and neck reconstruction in 16 patients (18.4 percent), and for lower extremity reconstruction in 28 patients (32.2 percent). Of the 87 flaps, 48 (55.2 percent) were based on a single perforator, whereas 39 flaps (44.8 percent) were based on multiple perforators. The single- and multiple-perforator–based thoracodorsal artery perforator flaps were compared regarding clinical outcomes and morbidity.
Results: The morbidity rate was found to be significantly higher in the single-perforator–based group. Of the patients in the single-perforator group, seven patients had transient venous congestion, five were heparinized and treated with leeches for permanent venous congestion, six had partial necrosis, and one had total necrosis. In the multiple-perforator–based group, two patients had transient venous congestion, and no partial or total necrosis was observed.
Conclusion: Despite the fact that dominant perforators may often be absent, this study showed that a multiple-perforator–based thoracodorsal artery perforator flap may be more reliable with safe vascularity compared with a single-perforator–based flap. (*Plast. Reconstr. Surg.* 128: 158e, 2011.)

The concept of the perforator flaps has helped to develop the thoracodorsal artery perforator flap pedicled with dominant musculocutaneous perforators from the thoracodorsal artery. Although Angrigiani et al.[1] were the first to report the thoracodorsal artery perforator flap in 1995, the thoracodorsal artery perforator flap was not as popular as other perforator flaps in the reconstructive era because of the difficulty of identifying the dominant muscular perforator intraoperatively and the unreliable vascularity of the flap.[2–7]

Recent anatomical studies regarding the vascularity and number of perforators of the thoracodorsal artery perforator flap promise more reliable results in harvesting,[8–12] yet clinical studies emphasize the vascularity problems that might be encountered, especially when the flap is based on

From the Department of Reconstructive and Aesthetic Surgery, Microsurgery, Faculty of Medicine, Bezmialem Vakif University; private practice; and the Departments of Plastic and Reconstructive Surgery of Dicle University Faculty of Medicine, Celal Bayar University Faculty of Medicine, Istanbul University Cerrahpasa Medical Faculty, Bakirkoy Acibadem Hospital, University of Acibadem, and Bezm-i Alem Valide Sultan Vakif Gureba Training and Research Hospital.
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a single perforator.[13] In the present study, we aimed to determine the clinical outcomes of single- and multiple-pedicle–based free thoracodorsal artery perforator flaps in 87 patients.

PATIENTS AND METHODS

Between November of 2004 and May of 2009, 87 patients (25 women and 62 men) underwent reconstruction using the free thoracodorsal artery perforator flap. In the present study, the principles outlined in the Declaration of Helsinki have been followed. All investigations in this study were carried out to a high ethical standard. All of the patients in the study were informed regarding the medical risks and benefits, and informed consent was obtained from each patient declaring the possible complications of the precise treatment recommended. The flap was used for upper extremity reconstruction in 43 patients (49.4 percent), for head and neck reconstruction in 16 patients (18.4 percent), and for lower extremity reconstruction in 28 patients (32.2 percent). Of the 87 flaps, 48 (55.2 percent) were based on a single perforator (Fig. 1) and 39 (44.8 percent) were based on multiple perforators (Fig. 2). The patient data, reconstructed area, number of perforators, complications, and donor-site morbidity are listed in Table 1.

In all of the patients, the perforators were identified using power Doppler ultrasound. During surgery, the patients were positioned in the lateral decubitus position, and a skin paddle was designed according to the perforators identified

Fig. 1. The thoracodorsal artery perforator free flap based on a single perforator.

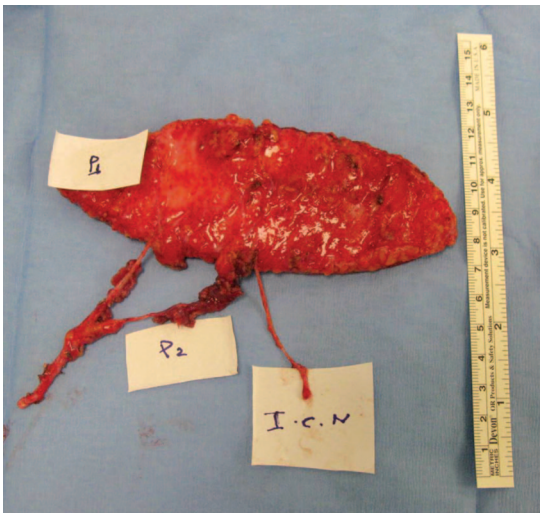

Fig. 2. The thoracodorsal artery perforator free flap based on three perforators.

(Fig. 3). After incision of the skin, the flap was harvested from the mediodorsal to the anterolateral direction. During fine dissection, the musculocutaneous perforators were identified, and the flap pedicle was based on the selected perforators (Figs. 4 and 5). The dissection advanced intramuscularly and small muscular branches were coagulated with bipolar cautery, and the perforator vessels were traced to the point of origin at the main descending thoracodorsal vessel. The vessel was then ligated inferiorly, and the pedicle was elevated toward the source of the thoracodorsal or subscapular pedicle superiorly in the axillary region, where it was divided (Fig. 6). Three flaps were harvested by dividing the pedicle at the descending branch of the thoracodorsal vessel to avoid a long pedicle and diameter discrepancy between the flap and recipient vessels (Fig. 7).

In the single-perforator group, seven end-to-side anastomoses to recipient vessels were performed, whereas in the multiple-perforator group, only three end-to-side anastomoses to the recipient vessels were performed. All end-to-side anastomoses that were performed for the arteries were carried out for lower extremity reconstructions.

The flap dimensions were 5 to 10 cm × 14 to 31 cm, and the donor area was closed primarily. All of the flap operations were performed by the authors of the present study, and although every surgeon might indeed have a learning curve, all flaps were harvested by skillful surgeons experienced with other types of perforator flaps.

The single- and multiple-perforator–based groups were compared in terms of clinical outcomes and morbidity. Statistical analyses were per-

Table 1. Patient Data, Reconstructed Area, Number of Perforators, Complications, and Donor-Site Morbidity

Patient	Sex	Age (yr)	Flap Size (cm)	No. of Perforators	Reconstructed Area	Complications	Donor-Site Morbidity
1	M	29	21 × 7	1	Upper extremity	None	None
2	M	37	19 × 8	1	Upper extremity	None	None
3	F	18	20 × 5	1	Upper extremity	None	None
4	M	31	18 × 6	1	Head and neck	Partial loss, PVC	None
5	F	26	20 × 6	1	Upper extremity	None	Seroma
6	M	22	19 × 7	1	Head and neck	TVC	None
7	M	38	16 × 10	1	Upper extremity	None	Superficial epidermal loss
8	M	31	15 × 8	1	Head and neck	None	None
9	M	13	20 × 9	1	Head and neck	Partial loss, PVC	None
10	M	5	15 × 5	1	Upper extremity	None	None
11	M	16	18 × 7	1	Upper extremity	None	None
12	F	23	20 × 9	1	Upper extremity	Partial loss, PVC	Seroma
13	F	32	18 × 8	1	Lower extremity	None	None
14	M	21	20 × 8	1	Upper extremity	None	None
15	M	51	20 × 9	1	Lower extremity	None	Superficial epidermal loss, seroma
16	F	18	15 × 8	1	Upper extremity	Partial loss, PVC	None
17	M	31	19 × 8	1	Head and neck	None	None
18	M	43	18 × 5	1	Upper extremity	TVC	None
19	F	71	20 × 7	1	Lower extremity	None	None
20	F	45	15 × 8	1	Head and neck	None	None
21	M	24	20 × 6	1	Lower extremity	TVC	None
22	M	19	25 × 5	1	Lower extremity	None	None
23	M	27	16 × 6	1	Upper extremity	None	None
24	F	48	25 × 8	1	Lower extremity	None	None
25	M	29	18 × 5	1	Upper extremity	None	None
26	M	23	20 × 9	1	Lower extremity	None	Superficial epidermal loss
27	M	62	15 × 7	1	Lower extremity	None	None
28	F	33	20 × 7	1	Upper extremity	None	None
29	M	6	15 × 4	1	Lower extremity	TVC	None
30	M	48	20 × 6	2	Lower extremity	None	None
31	M	14	25 × 6	1	Upper extremity	TVC	None
32	M	25	16 × 7	1	Lower extremity	None	None
33	M	14	17 × 9	1	Head and neck	None	None
34	M	39	18 × 5	1	Upper extremity	Total loss	None
35	M	21	15 × 5	1	Upper extremity	None	None
36	M	23	20 × 8	1	Lower extremity	Partial loss, PVC	None
37	M	19	17 × 5	1	Head and neck	None	None
38	F	22	15 × 5	1	Lower extremity	None	None
39	M	11	18 × 6	1	Lower extremity	None	None
40	M	57	15 × 7	2	Upper extremity	TVC	None
41	M	28	19 × 6	1	Lower extremity	None	None
42	M	31	23 × 8	1	Lower extremity	None	Seroma
43	M	7	19 × 9	3	Upper extremity	None	None
44	M	51	23 × 8	2	Upper extremity	None	None
45	M	27	14 × 5	2	Upper extremity	None	None
46	F	14	20 × 8	3	Head and neck	None	None
47	F	16	19 × 6	1	Lower extremity	TVC	None
48	M	42	17 × 6	1	Upper extremity	None	None
49	M	22	18 × 5	1	Upper extremity	None	None
50	M	25	17 × 6	1	Head and neck	TVC	None
51	F	9	20 × 8	2	Lower extremity	None	None
52	F	23	16 × 5	1	Upper extremity	None	None
53	F	7	15 × 8	1	Head and neck	Partial loss, PVC	None
54	M	19	26 × 8	3	Upper extremity	None	None
55	M	36	20 × 7	2	Lower extremity	None	None
56	M	19	21 × 8	2	Upper extremity	None	None
57	M	27	16 × 5	1	Head and neck	None	None
58	F	38	21 × 9	3	Upper extremity	None	None
59	M	25	14 × 5	2	Head and neck	None	None
60	F	23	26 × 9	3	Head and neck	None	Superficial epidermal loss
61	F	21	19 × 7	2	Lower extremity	None	None
62	M	43	20 × 8	2	Lower extremity	None	None
63	M	27	20 × 6	2	Upper extremity	None	None
64	M	19	24 × 9	3	Upper extremity	None	None
65	M	22	17 × 5	2	Head and neck	TVC	None

(*Continued*)

Table 1. (*Continued*)

Patient	Sex	Age (yr)	Flap Size (cm)	No. of Perforators	Reconstructed Area	Complications	Donor-Site Morbidity
66	M	22	24 × 8	2	Lower extremity	None	None
67	F	18	20 × 9	3	Upper extremity	None	None
68	M	36	21 × 7	3	Upper extremity	None	None
69	F	8	15 × 6	2	Upper extremity	None	None
70	F	20	25 × 9	2	Lower extremity	None	None
71	F	67	17 × 6	3	Upper extremity	None	None
72	M	16	18 × 5	2	Lower extremity	None	None
73	M	40	21 × 8	2	Upper extremity	None	None
74	M	23	19 × 8	3	Upper extremity	None	None
75	M	14	21 × 9	3	Head and neck	None	None
76	F	34	23 × 7	2	Lower extremity	None	None
77	F	69	31 × 9	3	Upper extremity	None	Seroma
78	M	12	22 × 8	2	Lower extremity	None	None
79	M	14	19 × 8	3	Upper extremity	None	None
80	M	35	16 × 5	2	Lower extremity	None	None
81	M	31	23 × 8	2	Upper extremity	None	None
82	M	7	15 × 5	2	Upper extremity	None	None
83	F	29	22 × 7	2	Upper extremity	None	None
84	M	38	30 × 8	3	Upper extremity	None	None
85	M	25	19 × 7	2	Upper extremity	None	None
86	M	25	26 × 8	2	Upper extremity	None	None
87	M	31	16 × 10	2	Upper extremity	None	None

M, male; F, female; PVC, permanent venous congestion; TVC, transient venous congestion.

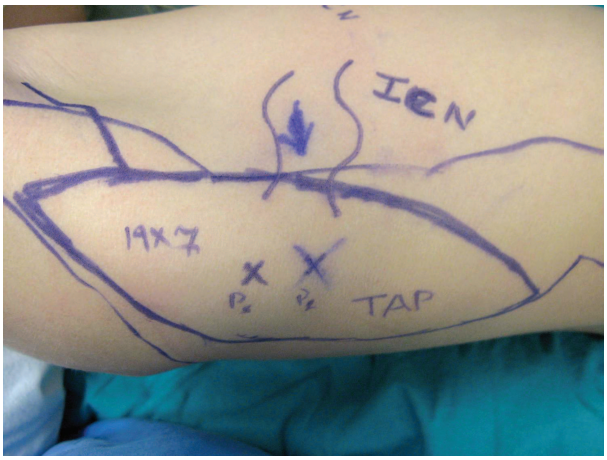

Fig. 3. The designed skin paddle of a thoracodorsal artery perforator flap with marked perforators.

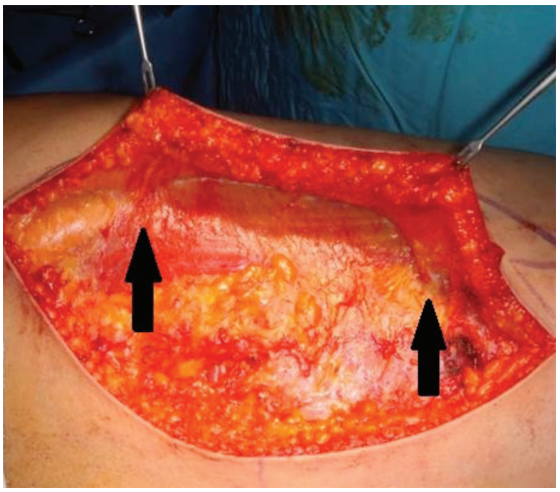

Fig. 4. The dissection was performed from mediodorsal to anterolateral; the *arrows* indicate the identified musculocutaneous perforators.

formed using SPSS version 15.0 (SPSS, Inc., Chicago, Ill.). Descriptive data are presented as the mean, SD, median, minimum, and maximum values for the continuous variables, and as frequency tables with percentages for the categorical variables. Categorical variables were compared using the chi-square test. The level of statistical significance was accepted as a value of $p < 0.05$.

RESULTS

The mean pedicle length, the number of multiple perforator–based flaps, and the mean distance between the thoracodorsal perforators are listed in Table 2. Of the patients in the single-perforator group ($n = 48$), seven (14.6 percent) had transient venous congestion and five (10.4 percent) were heparinized and treated with leeches for permanent venous congestion. Of three patients (6.3 percent of the 48) who underwent repeated surgery, the artery anastomoses were revised in two (4.2 percent) and the vein anastomosis was revised in one (2.1 percent). Moreover, six patients (12.5 percent) had partial necrosis, and one patient (2.1 percent) had a total loss of the flap because of arterial insufficiency. Of the patients in the multiple-perforator group ($n =$

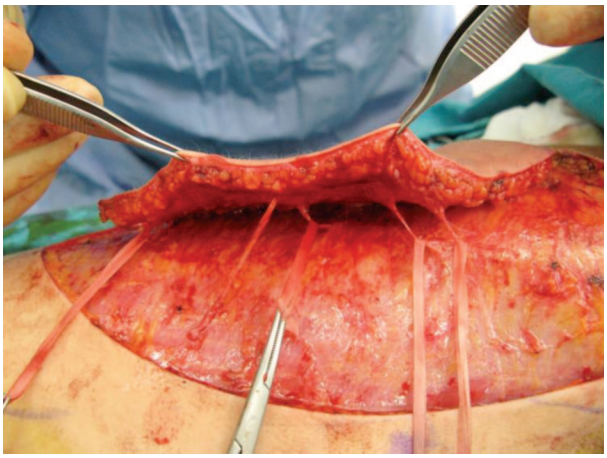

Fig. 5. The flap based on multiple musculocutaneous perforators.

39), two (5.1 percent) had transient venous congestion, one underwent repeated surgery for artery insufficiency, and no partial or total necrosis was observed (Table 3). The morbidity rate was found to be significantly higher in the single-perforator group. No necrosis was observed in the multiple-perforator group, whereas necrosis was observed in seven patients in the single-perforator group; the difference was significant ($p = 0.015$).

Transient Venous Congestion of the Thoracodorsal Artery Perforator Flap

Transient venous congestion, also referred to as temporary venous congestion, can be defined as a state of venous congestion occurring in free perforator flaps during the early postoperative period.[2,13] This condition usually appears on the third or fourth postoperative day. The flap becomes darker in color and gradually increases in congestion (Fig. 8, *left*). Approximately 10 to 15 days postoperatively, the dark color begins to change to a lighter form when the purpuric rashes resolve and edema is relieved progressively (Fig. 8, *right*). Finally, the flap returns to its normal texture and color by the end of 3 weeks postoperatively, with possible partial or superficial loss, mostly at

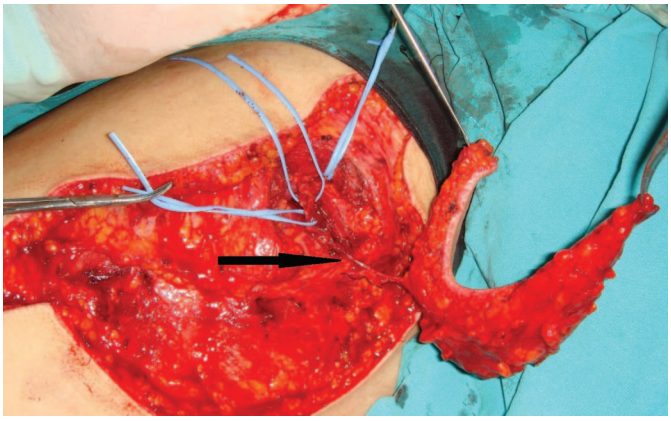

Fig. 6. The *arrow* indicates the thoracodorsal pedicle elevated superiorly toward the axilla.

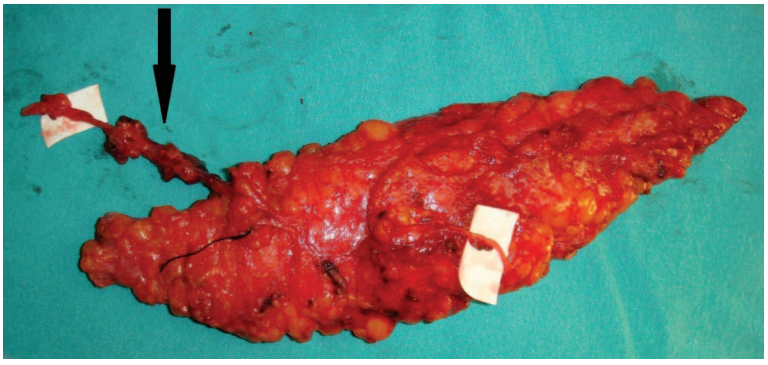

Fig. 7. The thoracodorsal artery perforator free flap based on a single perforator. The *arrow* indicates the short pedicle, which represents the descending branch of the thoracodorsal vessels.

Table 2. Intraoperative Measurements of Pedicle Length, Distance between the Thoracodorsal Perforators, and Number of Multiple-Perforator–Based Flaps

	Value
Mean thoracodorsal pedicle length	12.7 cm
No. of flaps based on two perforators	25
No. of flaps based on three perforators	14
Mean distance between first and second perforators	4.7 cm
Mean distance between second and third perforators	1.3 cm

Table 3. Complication Rates for Temporary Venous Congestion and Permanent Venous Congestion in Both Groups

	Single-Perforator Group (%)	Multiple-Perforator Group (%)	*p*
No. of patients	48	39	
Transient venous congestion	7 (14.6)	2 (5.1)	0.178
Permanent venous congestion	5 (10.4)	0 (0.0)	0.062
Revision operations			
Artery anastomosis	2 (4.2)	1 (2.6)	1.000
Vein anastomosis	1 (2.1)	0 (0.0)	
Complications			
Partial loss of flap	6 (12.5)	0 (0.0)	0.015
Total loss of flap	1 (2.1)*	0 (0.0)	

*Caused by arterial insufficiency.

the distal margins of the flap (Fig. 9). In this series, we observed that multiple-perforator–based free thoracodorsal artery perforator flaps rarely exhibited such characteristics, whereas single-perforator–based free flaps exhibited such characteristics more frequently.

DISCUSSION

The delicate and frustrating dissection of perforators of varying diameters and locations requiring prolonged surgery is perhaps the main disadvantage of the thoracodorsal artery perforator flap, yet this may be overcome by training and experience. Indeed, comprehending and perceiving the three-dimensional structure of the thoracodorsal vasculature enables the surgeon to be much more confident in harvesting it.

Recent anatomical studies have shown that the perforator vessels of the thoracodorsal artery perforator flaps are multiple and mostly originate from the descending branch of the thoracodorsal vasculature.[8–12] Thomas et al.[10] reported that the maximum area of skin that could potentially be supplied by the thoracodorsal artery averaged 600 cm^2, and the mean number of perforators that supplied this zone was 5.5. In contrast, in a topographic study of the thoracodorsal artery perforator flap, Mun et al.[11] isolated a mean number of 4.3 musculocutaneous perforators and reported that 48 of 99 of the perforators originated from the descending branch of the thoracodorsal vasculature. In their study, Schaverien et al.[12] reported at least one perforator originating from the descending branch of the thoracodorsal artery in all specimens. In addition, at least one perforator originating from the descending branch in all flaps was found between 9.5 and 15.4 cm from the posterior axillary fold, within 4.3 cm of the lateral border of the latissimus muscle. Moreover, 58 percent of all perforators from the descending branch and 39 percent of all perforators from the thoracodorsal artery were reported to be found in this region.

In our series, we selected our perforators according to the descending branch of the thoracodorsal artery in accordance with the previously conducted anatomical studies, and indeed, two to three perforators were included in the multiple-perforator–based flap group.

Preoperative perforator mapping is performed using Doppler imaging. Recently, multidetector row computed tomography has been introduced for the preoperative localization of various perforators.[14] Preoperative color Doppler sonography has been suggested as an indispensable tool for sensate thoracodorsal artery perforator flaps in locating the perforators and mapping the posterior divisions of the lateral cutaneous branches of the intercostal nerves.[15] Although preoperative Doppler imaging was performed routinely for mapping of the perforators, we certainly relied on the intraoperative exploration to locate the perforators. All flaps were harvested with patients in the lateral decubitus position, as routinely performed in harvesting the latissimus dorsi flap. After incision of the skin, dissection was started from the mediolateral aspect and continued until the perforators were identified.

The size of the flaps harvested varied (5 to 10 cm × 14 to 31 cm) and the flaps were planned in the vertical axis along the route of the descending branch of the thoracodorsal artery. In our series, all flaps were based on the musculocutaneus perforators, as described by Kim et al.[16–18]

Special care must be exercised while dissecting the perforators because they are extremely fragile and cannot withstand tension or traction forces. This is important, especially when the flap is based on a single perforator, as prolonged intraoperative dissection might lead to an irreversible vaso-

Fig. 8. A free thoracodorsal artery perforator flap based on a single perforator used for nose reconstruction in a burn case. (*Left*) The color of the flap darkened, with increased edema representing the state of transient venous congestion at postoperative day 5. (*Right*) Thirteen days after surgery, the color of the thoracodorsal artery perforator flap was changed to a lighter color and rashes resolved as the transient venous congestion state disappeared.

Fig. 9. Same patient as shown in Figure 8. (*Left*) Patient's appearance at postoperative day 20. The thoracodorsal artery perforator flap returned to its normal color and texture, with partial loss of the flap in its edges. (*Right*) The patient is shown at 4 months postoperatively. The nose was formed.

spasm or injury to the delicate veins. Furthermore, the thoracodorsal artery perforator flap is actually a low-output flap that has a poor and insufficient venous drainage[4] that may lead to transient or permanent venous congestion later. Recent studies[2–7,13] have shown that this problem is encountered mostly in flaps based on a single perforator, especially when the dominant perforator is not present. This fact may be the reason why permanent and transient venous congestion was more frequent in the single-perforator–based flaps in the present study. Only two of the multiple-perforator–based flaps exhibited transient venous congestion that resolved completely in 3 weeks. In addition, neither partial nor total loss of the flaps was observed. We believe that involvement of multiple perforators increases the reliability of the flap; moreover, delicate manipulation of the perforators is mandatory, especially with respect to the vein, because it is more vul-

nerable to shearing and twisting forces in comparison with the artery.

At the beginning of the study, the operative period was long when the flap was based on two or three perforators, and thus the operation was considered to be annoying. With a steep learning curve and cumulative experience, the dissection time was shortened dramatically to a period of 1 hour and harvesting of the flap became easier.

In their study in which 99 pedicled thoracodorsal artery perforator flaps were evaluated, Hamdi et al.[19] reported major flap necrosis in one case (1 percent) and limited partial or palpable fat necrosis in three cases (3 percent). In their study, Lee and Mun[20] successfully performed 31 free thoracodorsal artery perforator flap transfers, except for a single case of total flap loss. In the present study, six patients had partial necrosis and one patient had a total loss in the single-perforator group, whereas no partial or total necrosis was observed in the multiple-perforator group. The difference was statistically significant ($p = 0.015$).

CONCLUSIONS

The thin, pliable, large skin paddle combined with a long vascular pedicle is the advantage of the thoracodorsal artery perforator flap. However, harvesting the flap based on a single perforator, especially when the skin paddle is large, may put the viability of the flap in jeopardy. Therefore, the present study may suggest that involvement of multiple perforators to the flap might render the vascularity more secure and prevent the state of venous congestion.

Mehmet Veli Karaaltin, M.D.
Bezmialem Vakif University
Department of Plastic Reconstructive and Aesthetic Surgery
Faculty of Medicine
Adnan Menderes Bulvari
Istanbul, Turkey 34073
mkerkuk@yahoo.com

PATIENT CONSENT

The patient provided written consent for the use of her images.

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