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Algorithms for perforator-based flaps in different anatomical locations

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ABSTRACT

Introduction: Perforator-based flaps can be planned in any anatomic location in the body when there is a detectable perforator. Although preoperative perforator mapping ensures safety and versatility of these flaps, there is no consensus yet about flap planning in different anatomical locations.

Material and Method: 28 patients underwent perforator-based flap surgery for different anatomical locations as face (5), sternum (3), back (5), lomber (4), sacral (4) and scrotal (4) areas, leg (2) and foot (1). 19 of the patients were male while 9 were female. The mean age was 58.1±13.5 (22-80 years).

Perforator-based flaps were planned as V-Y design in face, sacral and scrotal areas while as perforator plus transposition flaps for lomber area, leg and sternum. On the other hand, for foot the flap was planned as subcutaneous-pedicled turnover flap.

Results: The mean follow-up time was 10 months (3-36 months). Partial flap necrosis is seen in all 3 patients who had underwent flap surgery on the lower extremity. There were no other complications seen in short- or long-term follow-ups. Comorbid diseases were not statistically significant on complications rates (P>0.05).

Conclusion: V-Y flap for the face and the sacral area; and perforator plus transposition flap for back ,lomber area and sternum are suggested as the ideal flap modifications for these anatomical locations. On the other hand, perforator-based flaps should not be used as a first choice in reconstruction of lower extremity defects.

Keywords: Perforator-based, versatility, flap modification, planning

INTRODUCTION

Perforator flap concept introduced security and versatility in the area of reconstructive surgery. Today, it is enough to plan a perforator flap for any anatomical location on the body if there is a perforator detected. The rules about mobility and design of the conventional flaps has been outdated with the emergence of perforator flap concept.

Conventional perforator flaps indicates dissection of the perforator from distal to proximal up to the source artery (1). Therefore, conventional perforator flap operations are microsurgical operations requiring expertise and sophisticated surgical instruments. Kim et al. (2) suggested that in perforator rich areas flaps can be transferred to the defect without perforator dissection. Flaps transferred to the defect without perforator dissection are called as "perforator-based flap". Perforator based flaps can also ensure similar advantages like security and versatility which were provided by conventional perforator flaps. Furthermore, they do not necessitate microsurgical expertise or sophisticated surgical tools reducing operating time is another advantage escipecially for co morbid patients who can not endure long operations.

Yıldırım et al. (3) suggested that as in the conventional perforator flaps, perforator-based flaps can also be planned in any anatomic location when there is detectable perforator present by a hand-held Doppler ultrasound. Concordantly, studies have showed that different perforator-based flaps can be planned in different designs for different anatomical locations as lower extremity (4), upper extremity (5), trunk (6), face (7) or scrotal area (8).

In all these studies, perforator-based flaps were defined for one anatomical location or single movement pattern and the authors suggested that the detection of the perforator is the only rule for planning perforator based flaps. In this study, we aim to define the important points that we consider when planning the flaps in different anatomical locations and present an algorithm.

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MATERIAL AND METHOD

The study was carried out with the permission of Balıkesir University Hospital, Noninvasive Clinical Researches Ethics Committee (Date: 23.02.2022, Decision No: 2022/34). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Records of 28 patients who had underwent reconstruction with perforator-based flaps were retrospectively investigated. Cause of the injury, anatomical location, movement pattern of the flap, comorbidities, complications and follow-up durations are obtained and listed in **Table 1**. Relationships of complications with comorbidities were investigated .

Data analysis was performed using IBM SPSS Statistics version 25.0 software (IBM Corporation, Armonk, NY, US). Shapiro-Wilk test was used to investigate whether the normal distribution assumption was met. Categorical data were expressed as numbers (n) and percentage (%) while quantitative data were given as mean ± SD and median (min-max). The mean differences between groups were compared Student's t test. Categorical data were evaluated Fisher's exact test. A p value less than 0.05 was considered statistically significant.

It was seen that perforator-based flaps were used in various anatomical areas such as face (5), sternum (3), back (5), lomber (4), sacral (4) scrotal (4) , leg (2) and foot (1). The flaps were planned as V-Y design in face, sacral and scrotal areas while as perforator plus transposition flaps for back ,lomber area, leg and the sternum. On the other hand, subcutaneous-pedicled turnover flap design

Table 1: Patient and flap demographics

Patient no	Age (year)/Sex	Comorbidity	Cause of defect	Defect Location	Defect size (cmxcm)	Pattern of flap	Flap size (cm)	Complications	Follow-up (months)
1	49/F	None	Trauma	Leg	4x3	Transposition-plus	15x5	partial necrosis	6
2	50/M	HT	Tumor	Back	5x1.5	Transposition-plus	6x3	None	12
3	58/M	DM	Fournier	Scrotum	15x8	V-Y	16x9&17x9	None	10
4	72/M	CAD-HT-DM	Postop dehiscence	Sternum	6x3	Transposition-plus	10x4	None	9
5	70/F	CAD	Postop dehiscence	Sternum	15x4	Transposition-plus	18x5	None	8
6	58/F	HT	Tumor	Back	4x3	Transposition-plus	6x3	None	16
7	67/M	HT-DM	Tumor	Face	3x2	V-Y	6x3	None	3
8	22/M	None	Trauma	Foot	4x2	Turnover	4x2	Partial necrosis	3
9	52/M	None	Tumor	Leg	4.5x2	Transposition-plus	9x3	Partial necrosis	10
10	45/F	None	Tumor	Back	5x3	Transposition-plus	8x4	None	18
11	62/M	None	Tumor	Back	6x4	Transposition-plus	10x4	None	22
12	65/M	None	Tumor	Face	3.5x1.5	V-Y	6x2	None	18
13	50/F	None	Tumor	Face	4x3	V-Y	6x3	None	5
14	79/M	CAD-PAD-DM	Decubitis ulcer	Sacral	15x10	V-Y	12x10 & 13x9	None	24
15	53/M	DM	Postop dehiscence	Lomber	8x4	Transposition-plus	13x4	None	28
16	41/M	None	Postop dehiscence	Lomber	12x8	Transposition-plus	14x7	None	36
17	41/M	DM	Fournier	Scrotum	15x10	V-Y	18x7&15x6	None	22
18	59/F	DM	Fournier	Scrotum	12x10	V-Y	10x8&14x8	None	24
19	58/M	ANAL FISSURE	Fournier	Scrotum	12x10	V-Y	14x9&12x8	None	3
20	57/M	None	Tumor	Face	3x2	V-Y	5x2	None	6
21	58/M	None	Tumor	Back	8x3	Transposition-plus	12x4	None	8
22	80/M	HT-DM	Decubitis ulcer	Sacral	15x9	V-Y	19x8&15x8	None	7
23	79/F	DM	Postop dehiscence	Sternum	14x5.5	Transposition-plus	19x5	None	9
24	58/M	DM	Postop dehiscence	Lomber	8x4	Transposition-plus	12x4	None	21
25	78/F	CAD-DM	Decubitis ulcer	Sacral	10x10	V-Y	14x4&15x6	None	24
26	71/F	CAD	Decubitis ulcer	Sacral	12x11	V-Y	10x3&16x4	None	10
27	49/M	None	Tumor	Face	3x2	V-Y	5x3	None	3
28	46/M	None	Postop dehiscence	Lomber	6x4.5	Transposition-plus	10x4	None	3

F: Female, M: Male, CAD: Coronary artery disease, HT: Hypertension, DM: Diabetes mellitus, PAD: Peripheral artery disease

was preferred for the foot .

RESULTS

36 flaps were performed in 28 patients who were included in this study. 19 of the patients were male (67,9%) while 9 were female (32.1%) and the mean age was 58.1±13.5 years (20-80 years) (**Table 2**) . 3 patients who perforator-based flaps used for lower extremity (2 leg, 1 foot) had partial necrosis .In one patient with partial necrosis who had reconstruction with perforator plus transposition flap on the leg, the defect after debridment of necrotic flap has left for secondary wound healing; while the other patient with partial necrosis on the leg, the defect skin grafted . For the partial necrosis developed after perforator-based turnover flap on the foot, the patient was referred to a higher center due to the necessity for a free-flap since vital structures were exposed.

Table 2. Demographic and clinical characteristics of cases

	n=28
Age (year) *	58.1±13.5
Range of ages (year)	22-80
Gender	
Female	9 (32.1%)
Male	19 (67.9%)
Comorbidity	
None	12 (42.9%)
DM	11 (39.3%)
HT	5 (17.9%)
CAD	5 (17.9%)
Other	2 (7.1%)
Cause of defect	
Tumor	11 (39.3%)
Postop dehiscence	7 (25.0%)
Decubitis ulcer	4 (14.3%)
Fournier	4 (14.3%)
Trauma	2 (7.1%)
Defect Location	
Back	5 (17.9%)
Face	5 (17.9%)
Lomber	4 (14.3%)
Sacral	4 (14.3%)
Scrotum	4 (14.3%)
Sternum	3 (10.7%)
Leg	2 (7.1%)
Foot	1 (3.6%)
Defect size (cm) **	7 (3-15)
Pattern of flap	
Transposition	16 (57.1%)
V-Y	11 (39.3%)
Turnover	1 (3.6%)
Lateralization	
Unilateral	8 (28.6%)
Bilateral	20 (71.4%)
Flap size (cm) **	12 (4-19)
Complications	
None	25 (89.3%)
Partial necrosis	3 (10.7%)
Follow-up (months) **	10 (3-36)

Descriptive statistics were shown as * mean ± SD or ** median (min-max). DM: Diabetes mellitus, HT: Hypertension, CAD: Coronary artery disease

The mean follow-up time was 10 months (3-36 months). There were no complications seen except of the lower extremity during the follow-ups .There were no relationship between complications and comorbidities (**Table 3**).

Table 3. Gender and comorbidity distributions in terms of complication status

	Patients without complication (n=25)	Patients with complication (n=3)	p-value
Gender			>0.999‡
Female	8 (32.0%)	1 (33.3%)	
Male	17 (68.0%)	2 (66.7%)	
Comorbidity			0.067‡
None	9 (36.0%)	3 (100.0%)	
Exist	16 (64.0%)	0 (0.0%)	

† Student's t test, ‡ Fisher's exact test

CASE REPORTS

Case no.5

A 70 year old woman was consulted from cardiothoracic surgeon for sternal wound dehiscence after 6 days from coronary artery by pass surgery .The wound was prepared for reconstruction with serial debridements and negative pressure wound therapy performed at 3 days intervals. After the third debridement 15x4 cm defect on the sternum was covered with perforator plus transposition flap which was raised on the internal mamarian artery perforator. The flap survived completely without any complication (**Figure 1 a,b,c**)

Case no.7

67 year old man referred with a biopsy proven basall cell carcinoma on the left nasal ala. The lesion was removed with 4 mm margin and 3x2 cm defect was left. The defect was covered with perforator based V-Y advancement flap which was planned parallel to the nasolabial fold. The patient healed uneventfully and scar was aesthetically pleasing (**Figure 2 a,b,c**).

Case no. 24

58 year old man referred for lomber defect developed after spinal surgery due to surgical site infection.After serial debridements and negative pressure wound therapy ,the wound was covered with perforator plus transposition flap (**Figure 3 a,b,c**).

Case no.26

A 71 year old man was referred with grade 4 sacral dekubitis .He has been paraplegic due to cerebrovascular event for nine years . The wound was debrided and 12x11 cm defect

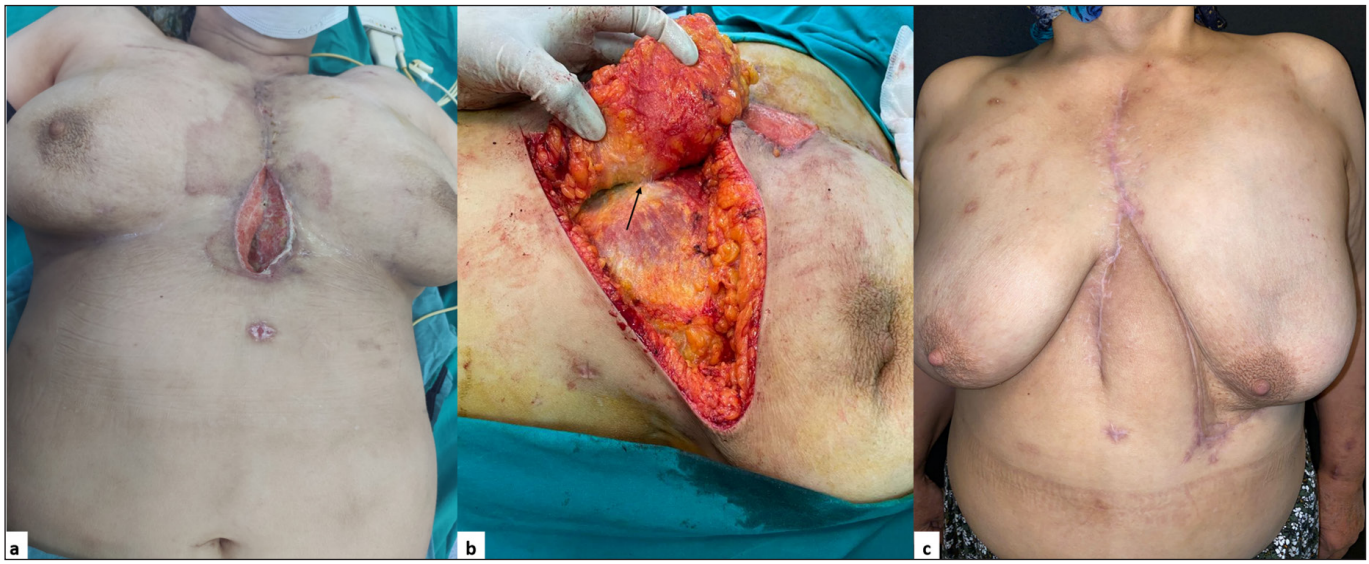

Figure 1a. Sternal wound dehcicence after coronary artery bypass surgery **b.** Perforator based transposition plus flap, arrow shows perforator from internal mamarian artery, which is visualised but not dissected intramusculary. **c.** Postoperative 4 months

Figure 2 a. Biopsi proven basal cell carsinoma on the nasal ala **b.** 3x2 cm defect on the nasal ala was planned to cover with perforator based V-Y advancement flap **c.** Postoperative results after 2 months

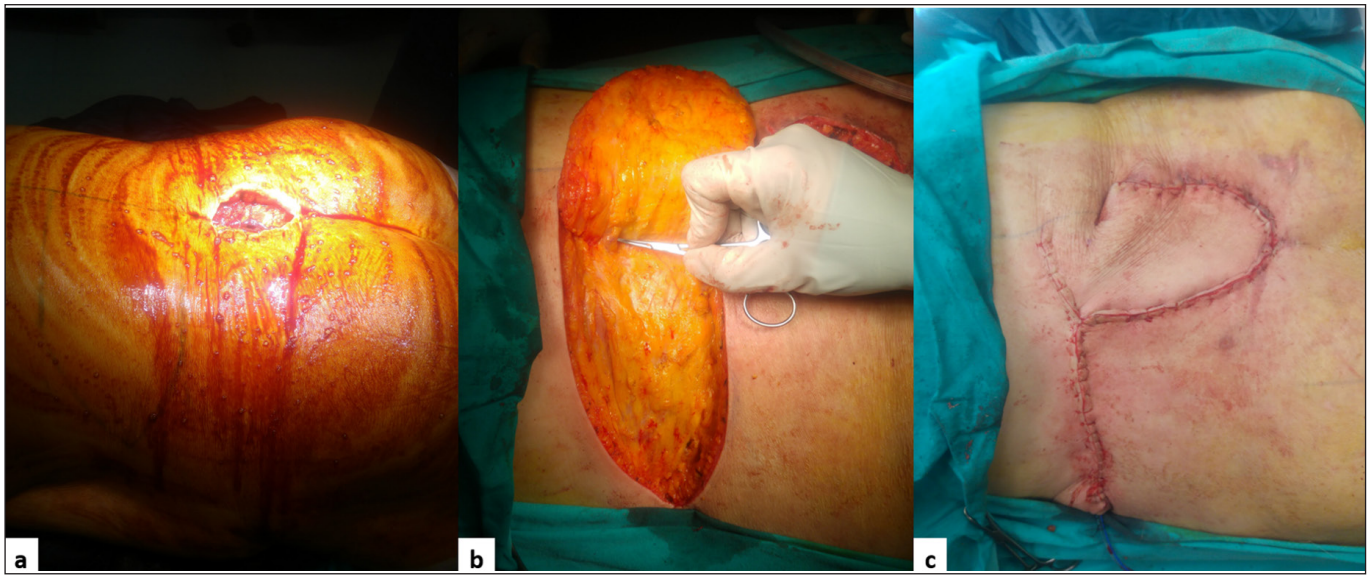

Figure 3 a. Lomber defect after neurosurgical procedure **b.** Flap elevated on one perforator shown at the tip of the clamp **c.** After closure

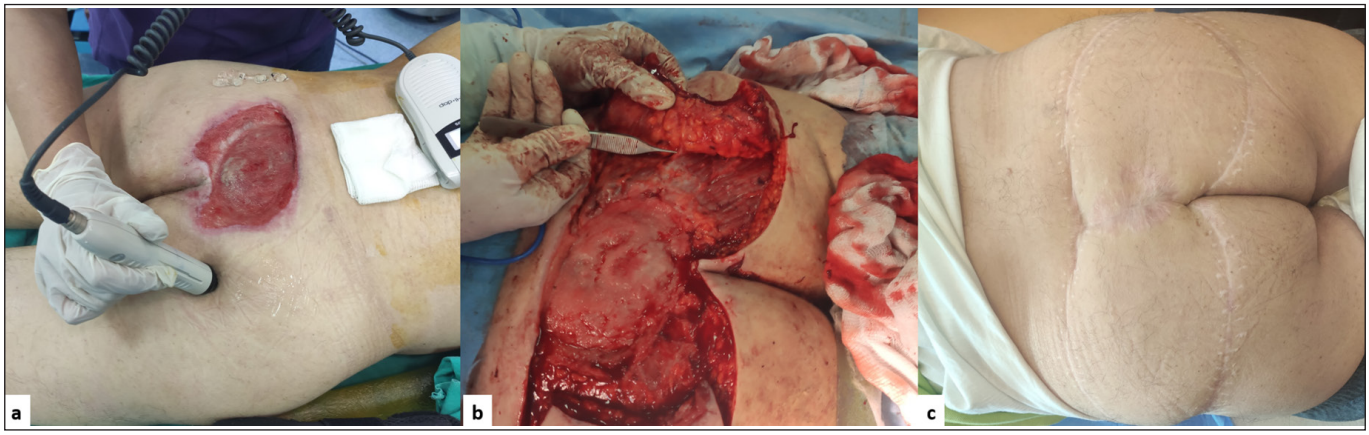

Figure 4 a. Sacral pressure sore , perforators are mapping with the handheld doppler **b.** Bilateral flaps were raised on a single perforator in each side, the perforator on the left side shown at the tip of the penset **c.** Postoperative 10 months

was left. Perforator vessels were detected with a handheld Doppler bilaterally in the gluteal regions and perforator based V-Y advancement flaps were raised on a single perforator ,bilaterally . The donor sites were closed primarly .Postoperative course was uneventful (**Figure 4 a,b,c**).

DISCUSSION

With the emergence of perforator flap concept, restrictions arising from conventional flap flap planning have been eliminated ; such as the length/width ratio for random flaps is no longer required for perforator flaps baceuse a perforator flap size can be planned according to the defect size (1,9,10). There is no need for inclusion of subfascial plexus in order to increase the perforator flap viability; and the flap thinning can be performed as wanted while preserving functional structures. Location-specific flap design is no longer necessary since a perforator flap can be harvested anywhere in the body when there is a detectable perforator.

Perforator flap means by definition that the perforator which nourishes the flap needs to be dissected until the source artery . Therefore, conventional perforator flap operations are sophisticated and long lasting operations. Perforator-based flaps, on the other hand, does not necessitate dissection of the perforator artery up until the source artery but only requires identification and preservation of the perforator artery (2-8). Since there is not a pedicle dissection, it does not require sophisticated microsurgery tools and take a shorter time to perform. Yıldırım et al (3) suggested that suprafascial dissection of the perforator vessels could be enough for the mobilization in the areas with adequate laxity. Furthermore, Kim et al. (2) propounded that in perforator rich areas these flaps could be harvested just by visualizing the perforator vessels without any dissection.

All these advantages of perforator-based flaps put them forward in the clinical practice and many studies are published in respect of their use in different anatomical locations on the body. However, in these studies only the liberty in flap planning that perforator flaps provide us was depicted and a detectable perforator was presented as the only entailment for the surgery (2-8). In this study, we aim to suggest the important points in flap planning apart from presence of detectable perforator; and present the algorithm that we established in the flap planning .

In this study, perforator-based flaps for the face were planned as V-Y advancement flaps; therefore, trapdoor deformity seen in transposition flaps were avoided. Furthermore, we suggest in keeping with literature (11) that V-Y advancement flaps adapt better with relaxed skin tension lines (RSTL) and dynamic skin tension lines (DSTL) providing better esthetic outcomes.

For the sternal and lomber defects, we used perforator-plus transposition flaps. Perforator-plus transposition flap is harvested by preserving skin paddle on the flap base. Preserving skin paddle is suggested to contribute arterial and venous circulation of the flap (12,13). We suggest using perforator-plus transposition flaps on the trunk is quite easy and convenient; also, preserving skin paddle does not interfere with the flap transposition. Dog-ear deformity is not seen as in traditional transposition flaps since dissection at the basis of the perforator is possible providing better mobility. Furthermore, there is not an obligation to follow the rule that length-to-width ratios are not to exceed 3:1 as in random flaps. Literature also shows that perforator-based flaps on the trunk with ratios of 1:4 or 1:5 are totally viable (14,15). This advantage of perforator-based flaps is quite important especially for long defects seen after coronary artery bypass complication since it enables to use a single flap to reconstruct the defect while causing less donor site morbidity.

We come up with partial flap necrosis in all patients reconstructed with perforator-based flaps for their lower extremities. In a study showing 400 the perforators identified in the body it was suggested that 93 of these

perforators are found in the lower extremity (16). On the other hand, necrosis ratio on the lower extremity has been shown higher than the ratios on the other areas of the body in several studies (3,4,17). Our results were also in rapport with these studies. We claim that worse tissue laxity in the lower extremity cause poor flap mobility. Although preserving the perforator ensures better security, too much tension can cause arterial or venous insufficiency endangering the perforator flap viability. Therefore, we suggest not to use perforator-based flaps as the first choice in reconstruction of lower extremity, or at least avoid dissections that can endanger harvesting conventional flaps as backup plan after perforator-based flaps.

Perforator-based V-Y advancement flaps from medial thigh were used for scrotal reconstruction. As regards to large defect size, usually bilateral flaps were planned and used. Although V-Y advancement flaps requires larger incisions compared to transposition flaps, V-Y advancement flaps were preferred since they constitute more natural inguinoscrotal fold which is constantly exposed to friction during walking. Although there are studies showing large linear incisions taking longer time to heal and causing scar contractures (18), we did not encounter any similar problems in our patients.

Perforator-based flaps are especially preferred in patients with pressure ulcers and comorbid diseases since they are harvested quickly decreasing anesthesia duration and side effects. Detection of the perforator provides us to dissect the flap base more extensively allowing increased flap mobility (19,20). Furthermore, Bonomi et al. (21),suggested that perforator bsed V-Y advancement flap can be designed with Pacman modification to enhance soft tissue coverage for the defect. We preferred perforator based flap in a V-Y advancement design essipecially for cachectic patients and when the donor site laxity did not allow primary closure. (Which is checked with pinch test.) Since flap dissection can be made more extensively than the conventional random V-Y advancement flap, these flaps have great mobility thus enabling bigger defects can be covered with smaller flaps. Besides their donor sites can be closed primarily.

In our study, we also showed that comorbidities do not have a significant effect on flap survival (P>0.05). Although number of cases in this study were small to evaluate the effect of patients spesifics on complications , this result conforms with literature. Chih-Hsun et al. (22) showed that local factors have a more significant effect on flap survival than systemic factors. They suggested that perforator vessel size detected during the dissection, its pulsatility, twisting or tension during flap adaptation are the most significant factors affecting flap survival.

This study has some limitations. The small number of cases prevented statistical comparisons. For example there are only three patients who developed complications. All complications were in the lower extremity which is a well defined anatomic localization for complications. It was hard to compare patients' spesifics which can be related with the complications because of the small number.

CONCLUSION

Perforator-based flaps can be designed in any location on the body if there is a detectable perforator present. Since better suits with facial lines, V-Y advancement flaps are preferred on the face; while perforator-plus transposition flaps yield better results on the anterior and posterior trunk. For the lower extremity, flap necrosis rates higher than the other anatomic localisations of the body therefore, perforator-based flaps should not be the first choice for the lower extremity. Nevertheless, if perforator-based flaps are planned to be used anyway, then avoid dissections that can endanger harvesting conventional flaps as backup plan.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Balıkesir University Hospital, Noninvasive Clinical Researches Ethics Committee (Date: 23.02.2022, Decision No: 2022/34).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper and that they have approved the final version

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