Freestyle Perforator Puzzle Flap for Posterior Trunk Reconstruction

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Background: Closure of extensive defects of posterior trunk can be challenging for reconstructive surgeons owing to the need of a large bulk of well-vascularized tissue to resurface the skin and the exposed hardware and to fill the dead spaces. We hypothesized that elevating multiple perforators flaps in various patterns would allow for reconstruction of large posterior trunk defects with tension-free primary closure and minimal donor site morbidity.

Patients and Methods: Between January 2013 and December 2016, 23 patients with large posterior trunk defects underwent reconstruction with a multiple freestyle perforator flaps approach. We experimented a freestyle perforator-based reconstruction, which consists of designing a sequence of flaps, able to adequately fit the defects, allowing for tensionless primary closure.

Results: The average age of patients was 60.2 years (range, 18–80 years). A total number of 62 perforator flaps was performed, with an average of 2.6 flaps per patient. We were able to successfully cover defects up to 27 × 29 cm. A single perforator was used in 58 flaps, whereas more than 1 perforator was applied in 4 flaps. In all cases, the donor sites were closed primarily, and patients healed uneventfully. Six patients underwent radiotherapy after surgery, but no complication occurred.

Conclusions: In this series of extensive defects of the posterior trunk, a tension-free closure was achieved by distributing the tension to multiple freestyle perforator flaps, supplying sufficient volume of tissue and reliable vascularization. This approach can be a valid tool in facing reconstruction of large and complicated defects of the posterior trunk.

Key Words: posterior trunk reconstruction, trunk reconstruction, propeller flap, freestyle perforator flap, freestyle perforator puzzle flap, perforator flap

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The reconstruction of the posterior trunk offers special challenges to plastic surgeons, given the relative shortage of elasticity and wide extent as well as a deficiency of potential microsurgical recipient vessels.[1–3] Soft tissue defects of posterior trunk may occur from removal of malignant skin or soft tissue tumors, infection, trauma, spine surgery, radiation ulcers, and congenital malformations.[4–6] Defects of the posterior trunk often involve hardware exposure, infection of bone, and poor healing wounds as a result of radiation therapy or bedsores. Therefore, it is mandatory to provide adequate coverage with well-vascularized tissues and to obliterate any possible dead spaces.[6]

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Primary wound closure implemented with skin grafts or local random transposition flaps can be useful to cover small- to moderate-sized defects, but it can offer a poor alternative for the patient with a complicated wound of the dorsum.[6] Local muscle and musculocutaneous flaps gained widespread approval in posterior trunk reconstruction owing to their ability to both fill and provide an adequate coverage for extensive wounds, especially those involving the spinal column.[6–8] However, large defects often require multiple local muscle flaps to achieve adequate coverage, resulting in increased donor site morbidity and impairment of the posterior trunk. For larger wounds, free flaps may be required, but isolating a reliable recipient pedicle can be challenging.[1–3] To overcome the limitation in obtaining a suitable recipient vessel, the use of free flaps implemented with arteriovenous loops and interposition grafts has been reported along with a remarkable increase in risk of complications.[9,10]

The application of perforator flaps has expanded the horizons of plastic surgery and has gained a prominent role in posterior trunk reconstruction, because this anatomical region provides abundant perforators.[11–14] Propeller flaps have been exploited for the reconstruction of the lumbar region in place of the less accessible free tissue transfer. The benefits of perforator-based propeller flaps rely on covering various defects of the posterior trunk while sparing muscles and surrounding structures, providing sufficient bulk and minimal donor site morbidity.[1,4,6] With the understanding that any perforator can be used to support a flap, the freestyle flap approach increased the possibilities of reconstruction, allowing for flexible, multiple and personal design of flaps.[13]

After this concern, for selected cases of complex defects not amenable to be reconstructed by a single-freestyle perforator flap, we designed a multiple flaps approach using a combination of freestyle perforator flaps. By designing with accuracy, we supposed that this approach will be adequate to reconstruct even extensive and large posterior trunk defects, with tension-free primary closure and minimal donor site morbidity. In this article, we report about our personal design and experience, prove the feasibility, and discuss the indications and the limitations of this approach.

PATIENTS AND METHODS

Between January 2013 and December 2016, 92 cases of posterior trunk defects were referred to our departments. Among these, 23 patients underwent reconstruction with multiple freestyle perforator flaps approach. In this article, we retrospectively reviewed this series. The average age of patients was 60.2 years (range, 18–80 years), and 14 patients were male (Table 1). Five patients were smokers, and 2 had been diagnosed as having diabetes. The defects resulted after excision of skin cancer (17 cases), wound dehiscence (1 case), and pressure sore (5 cases). One case presented with exposure of hardware and 3 patients with an infection, diagnosed through a positive culture swab. The defect sites were upper and middle back (14 cases), flank and posterolateral dorsum (2 cases), and lower back (7 cases) (Table 1).

Table 1 accounts for patients' age, anatomic location of the lesion, etiology, defect size, number of flaps used, and complications.

Operative Technique

After wide excision or careful debridement, the defects were evaluated in terms of dimension, anatomic location, thickness, and

TABLE 1. Characteristics of the Patients and Defects

	Age, y	Sex	Location	Etiology	Size, cm × cm	No. Flaps	Complications
1	51	F	Middle	Squamous cell carcinoma	27 × 29	3	None
2	63	M	Lower	Squamous cell carcinoma	28 × 15	2	Minimal wound dehiscence
3	18	M	Upper	Melanoma	10 × 12	2	None
4	73	M	Middle	Wound dehiscence	13 × 15	2	None
5	79	F	Lower	Pressure sore	14 × 9	3	None
6	36	M	Middle	Dermatofibrosarcoma	15 × 16	3	None
7	66	F	Lower	Pressure sore	23 × 19	3	None
8	64	M	Upper	Squamous cell carcinoma	20 × 13	3	None
9	57	F	Upper	Liposarcoma	23 × 21	4	None
10	49	M	Middle	Melanoma	17 × 21	3	None
11	75	F	Lower	Pressure sore	24 × 16	3	Minimal wound dehiscence
12	69	M	Lateral	Squamous cell carcinoma	15 × 7	2	None
13	58	M	Middle	Dermatofibrosarcoma	16 × 12	2	None
14	71	M	Middle	Melanoma	14 × 16	3	None
15	80	F	Lower	Pressure sore	14 × 10	3	None
16	39	F	Lateral	Melanoma	13 × 17	2	None
17	67	M	Middle	Squamous cell carcinoma	28 × 19	2	None
18	61	M	Middle	Dermatofibrosarcoma	19 × 12	3	None
19	58	F	Lower	Squamous cell carcinoma	20 × 21	3	None
20	51	M	Middle	Dermatofibrosarcoma	16 × 19	2	None
21	74	F	Lower	Pressure sore	21 × 14	3	None
22	68	M	Upper	Squamous cell carcinoma	14 × 8	2	None
23	59	M	Upper	Dermatofibrosarcoma	18 × 13	3	None

Size of the defect expressed as (length × width in centimeter).

hardware exposure. In all cases, portable ultrasound Doppler was used for mapping the perforators adjacent to the defect. At least 5 perforators were identified, and plausible multiple flaps were considered. On the basis of the intensity of the Doppler, dissection was carefully performed on the suprafascial plane under loupe magnification with meticulous hemostasis, to visually identify the highest signal perforator first. Pedicles were located and further protected by a careful dissection, deep enough to allow for twisting and free movements of the pedicle without kinking. The reliability of the perforators was determined by caliber and valid pulse as the most important signs. With an acceptable pedicle secured, the flap was then designed around the perforator/s as a freestyle flap, taking donor site closure and flap volume into account. All the flaps were designed according to the perforasome theory. For each case, we took into consideration the anatomy of the perforators, the geometry and the size of the defect, and the caliber of the pedicle. According to these considerations, we designed flaps with a shape that would fit the defect and allow for a closure without tension. The flap was then elevated and mobilized to cover the defect while attention was given to prevent the pedicle from kinking or tension. Once the first flap was positioned, a second flap was designed as previously described and so on until complete closure of the defect. This multisteps approach increased the reliability of the design. After the design and the rotation of the flaps, drains were then placed and donor sites primarily closed.

RESULTS

A total of 62 perforator flaps were performed, with an average of 2.6 flaps per patient (Table 1). In 58 flaps, a single perforator was used for each flap, and in 4 flaps, more than 1 perforator was used. The presumed origin of the perforators was from posterior intercostal arteries in 38 flaps, from circumflex scapular in 4 flaps, and from lumbar arteries in 17 flaps, and 3 superior gluteal arteries. In no case, the reconstruction with freestyle puzzle flaps was coupled with random flaps to cover the donor site. In all cases, the donor sites were closed primarily. In 2 flaps, some congestion was noted in the distal edge of the flap, and a grade of peripheral disepithelization was performed to release the congestion. Two flaps reported minimal wound margin dehiscence, but they did not require any surgery and healed by second intention. The drain was removed within 2 weeks (range, 7–12 days). All cases healed uneventfully without flap loss. Six patients underwent radiotherapy after surgery, but no complication occurred.

Two cases are herein reported as examples of the multiple freestyle puzzle flaps approach.

Case 1

A 51-year-old female patient presented with a diagnosis of a squamous cell carcinoma of the middle back (Fig. 1A). Perforators were marked preoperatively using a portable Doppler. After excision of the tumor, a 27 × 29-cm-sized defect was obtained with muscle and tendon exposure (Fig. 1B). Using the freestyle approach, perforators were presumed to be originating from the posterior intercostals, circumflex scapular, and lumbar arteries. On the basis of each perforator, one propeller flap and 2 advancement flaps were designed and move to cover the defect (Fig. 1C). A tension-free closure was achieved (Figs. 1D, E). The patient healed uneventfully. At 2 years of follow-up, no complication was observed.

Case 2

A 67-year-old male patient was referred to our plastic surgery service. A squamous cell carcinoma of the middle back was diagnosed (Fig. 2A). After wide excision, the defect size was 28 × 19 cm with

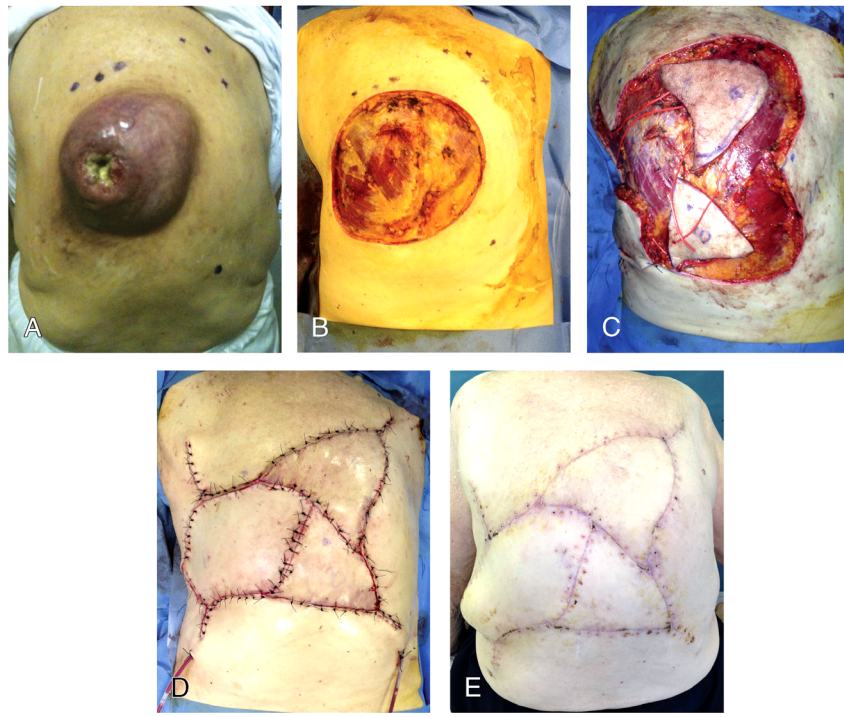

FIGURE 1. A, A 51-year-old female patient presented with a diagnosis of a squamous cell carcinoma of the middle back. A and B, Perforators were marked preoperatively, and after wide excision, the defect was 27 × 29 cm in size with muscle and tendon exposure. C and D, Using a freestyle approach, multiple perforators were marked around the defect, and on the basis of each perforator, 1 propeller flap and 2 advancement flaps were designed and rotated to cover the defect. D, A tension-free closure was achieved. E, The patient healed uneventfully, and at 2 months of follow-up, no complication was observed. full color online

muscle and tendon exposure. With the freestyle approach, perforators presumed to origin from the posterior intercostal arteries were isolated (Fig. 2B), and then 2 flaps were designed (Fig. 2C). The flaps were mobilized toward the defect area, and donor site was closed primarily (Figs. 2D, E). The flaps healed uneventfully, and no complication occurred during the follow-up period.

DISCUSSION

Closure of extensive defects of the posterior trunk still represents a challenge for reconstructive surgeons owing to the need of a large bulk of well-vascularized tissue to resurface the skin and the exposed hardware and to fill the dead spaces.[1,2] Hence, reconstruction of the

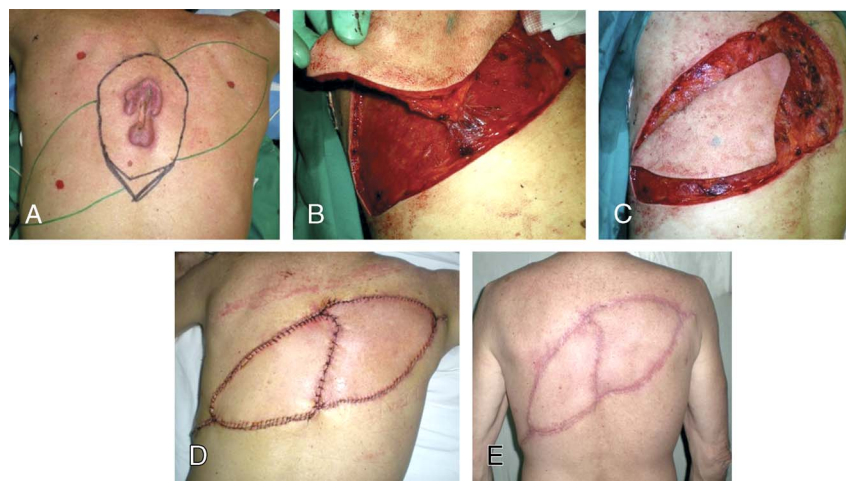

FIGURE 2. A, A 67-year-old male patient was diagnosed as having squamous cell carcinoma of the middle back. After wide excision, the defect size was 28 × 19 cm with muscle and tendon exposure. With the freestyle approach, perforators presumed to origin from the posterior intercostal arteries were isolated (B), and then 2 flaps were designed (C). D, The flaps were mobilized toward the defect area, and donor site was closed primarily. E, The flaps healed uneventfully, and no complication occurred at 1-month follow-up. full color online

posterior trunk requires careful analysis of the defect and appropriate selection of the covering tissue.[6]

The goals of any ideal reconstruction should be preserving functions and range of motion, providing adequate coverage and lessening donor site morbidity as much as possible, despite the dimension of the defect.[1,4] Although local random and muscle flaps such as latissimus dorsi, trapezius, paraspinosus, and gluteus maximus muscle flaps are suggested as the mainstream surgical option, they are not suitable to reconstruct all the large and complicated defects, ensuring a tension free closure and low donor site morbidity. Free flaps can be advocated as an alternative, although isolating reliable recipient vessels can be difficult.[1–4]

More recent techniques proposed the application of perforators and the perforasome concept.[14–19] The rational of using perforators to elevate a flap was first proposed by Taylor and Palmer,[14] after their studies on angiosomes. This approach involves harvesting a sizable skin flap based on a single perforator and moving it almost like a propeller to cover the defect, sparing the adjacent muscle and preserving function, while providing reasonable coverage.[11,12] Freestyle perforator propeller flaps have already been evaluated as a reliable and a simple solution to reconstruct difficult defects of the posterior trunk.[1–4] The posterior trunk seems particularly suitable for this approach, as the dorsum has abundant perforators, which allow for several designs of flaps and adequate coverage of the defect.[18]

We supposed that elevating multiple perforator flaps with different patterns would draw near reaching the goals of the ideal reconstruction, enabling a tension-free primary closure with minimal donor site morbidity. Furthermore, this design avoids the need of skin grafts, which are often necessary for the reconstruction of large defects of the back. We experimented a freestyle perforator reconstruction, which consist of a sequence of flaps, able to adequately fit the defects, allowing for corresponding closure between each other. Like in the popular chocolate bar brain teaser, a lack of a piece is replaced by a sequence of interchangeable movement of the other pieces that provides a final reconstruction, apparently mimicking no loss of substance. Because this approach proposes a step-by-step solution to the brain teaser of complicated reconstructions of the posterior trunk, we named it "perforator puzzle flap."

In our review, 23 of 92 cases could not achieve closure with one flap. To avoid tight closure and reduce the possibility of breakdown of the sutures, we achieved tension-free reconstruction of extensive wounds, designing multiple freestyle perforator flaps. We were able to successfully cover defects up to 27 × 29 cm using an average of 2.6 perforator flaps per patient without any vascular compromise of the flaps.

According to the freestyle approach, we were not able to point with certainty the source of the pedicle of each flap. However, we reported successful outcomes without any sufferance of the flaps. We think that the reliability of the freestyle design is due to the plethora of perforators that inhabits the posterior trunk and originates from different main arteries.[18] Several studies indicated the possible sources of the vessels of the posterior trunk: posterior intercostals arteries, circumflex scapular artery, lumbar arteries, superior epigastric artery, deep inferior epigastric artery, superficial inferior epigastric artery, superior circumflex iliac artery, superior gluteal artery, and deep circumflex iliac artery.[1,4,6]

Although Saint-Cyr et al[18] speculated that the flaps should be designed along the horizontal axis of the posterior trunk based on the perforasome theory, we elevated some of the flaps of our case series in a vertical fashion. However, we did not report any complications. As already hypothesized, a possible explanation is that maybe the flaps did not extend over different angiosomes territories.[4]

We only reported a venous congestion in 2 flaps. In these cases, we performed a sum of disepithelization, which worked as a natural way of discharge, preventing sufferance of the flaps.[19] However, we did not report any necrosis, and thus, we support the speculations that venosomes may be different from angiosomes.[4] Because this issue is still debated, further studies are warranted to determinate an ideal map of the arterial and venous circulation of the back.[4]

In this freestyle approach, the outcomes are not always predictable, as some perforators could be found to run in unexpected route, so we suggest to always look preoperatively for several perforators around the defect by Doppler-assisted evaluation.

Furthermore, a fundamental pillar of the ideal reconstruction is to provide similar tissues in terms of thickness and skin texture. The freestyle perforator–based approach uses the skin surrounding the defects, perfectly fitting the principle of replacing "like with like."

The concept of using multiple flaps or multilobe design flap for posterior trunk reconstruction is not new.[4,20–23] Cöloğlu et al[20] described a bilateral propeller flaps approach based on posterior intercostal and lumbar artery perforators for the closure of a series of large thoracolumbar meningomyelocele defects. In a recent study, Park et al[4] designed a similar freestyle approach, in which the flaps taken together resemble a jigsaw puzzle, but using also random flaps to close the defects. Our design differs from the previous reports because it uses more than a single perforator flap and figures a reconstruction in a total freestyle perforator–based approach. Furthermore, this series is the largest reported in the literature, as far as we are concerned.

CONCLUSIONS

The ideal method for reconstructing extensive defects of the posterior trunk is yet to be found. In this study, we achieved a tension-free closure by distributing the tension to multiple freestyle perforator flaps, supplying sufficient volume and reliable vascularization. This approach could be a valid tool for the reconstruction of large and complicated defects of posterior trunk.

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