Free-style Deepithelialized Propeller Flaps: An Ideal Local Flap to Obliterate Wounds with Dead Space

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Background: The reconstruction of the posterior trunk, especially with large dead spaces, remains challenging. Regional muscle flaps may lack adequate volume and reach. The purpose of this report was to evaluate the efficacy of deepithelialized free-style perforator-based propeller flaps to obliterate defects with large dead space.
Methods: A total of 7 patients with defects on the posterior trunk with large dead spaces were evaluated. After complete debridement or resection, all flaps were designed on a single perforator adjacent to the defect, deepithelialized, and then rotated in a propeller fashion. Flaps were further modified in some cases such as folding the flap after deepithelialization to increase bulk and to obliterate the dead space.
Results: The flap dimension ranged from $10 \times 5 \times 1$ to $15 \times 8 \times 2.5$ cm based on a single perforator. The rotation arch of the flap ranged from 90 to 180 degrees. Uneventful healing was noted in all cases. One case showed latent redness and swelling at 7 months after falling down, which resolved with medication. During the average follow-up of 28 months, there were no other flap and donor site complications.
Conclusion: The deepithelialized propeller flap can be used efficiently to obliterate dead spaces in the posterior trunk and retains advantages such as having a good vascular supply, adequate bulk, sufficient reach without tension, and minimal donor site morbidity. *(Plast Reconstr Surg Glob Open 2017;5:e1249; doi: 10.1097/GOX.0000000000001249; Published online 16 March 2017.)*

INTRODUCTION

Posterior trunk defects with large dead spaces remain difficult to heal. These defects may result from trauma, pressure sores, tumor, postoperative wound infection, dehiscence due to spine surgery, radiation injury, and burn injuries. Skin coverage of these wounds can be very deceptive as failure to obliterate dead spaces can result in secondary complications. In such cases, complete debridement, obliteration of the dead space with a well-vascularized tissue, should be one of the primary concerns along with skin closure.

To provide obliteration of dead spaces for trunk defects, muscle flaps such as lattissimus dorsi, gluteus maximus, trapezius, and paraspinous were described in previous articles.[1–3] Although very successful in achieving the primary objective, these flaps may still lack volume if the dead space is large and have difficulty in reaching the midline defects. Donor site morbidity is also a potential concern due to decreased function and pain.[1–3]

Hyakusoku et al.[4] introduced the concept of propeller flaps. They described using a perforator-based fasciocutaneous or adipocutaneous flap near the defect, which can rotate up to 180 degrees, allowing the coverage of the adjacent soft-tissue defect. These flaps can be elevated with large dimensions, but the design can be ideal if the donor site can be closed primarily. Previously, a partially deepithelialized superior gluteal artery perforator propeller flap was used to cover lower midline defects of the back.[5,6] But with the increased knowledge on perforasomes and free-style approach, custom-designed propeller flaps can be based on any perforator and any part of the body with an acceptable scar in the donor site while maintaining the muscle function beneath the skin.[7–12] In this article, we report our experience with totally deepithelialized propeller flap buried to obliterate various posterior trunk defects with dead space.

PATIENTS AND METHODS

This report is a retrospective review of patients who utilized the total deepithelialized perforator-based propeller flaps for their trunk defects between January 2010 and July 2015. This review was approved by the institutional review board of Asan Medical Center, Seoul, Korea. A total of 7

patients with an average age of 51.7 (between 31 and 68 years; 5 men and 2 women) years were reviewed. Among the 7 patients, initial causes for these defects were tumor in 4 cases, nephrectomy, burn, and degenerative kyphosis. Four patients were referred to plastic surgery department due to wound infection and dehiscence from previous surgery and 3 referred during the initial surgery due to unexpected defect formation. Five defects were located on the midback including a coccyx lesion and the other 2 were located on the right ischium and right flank. All wounds required a 3-dimensional closure as the defects were noted with large dead spaces from $2 \times 2 \times 3$ to $10 \times 7 \times 10$ cm without skin defect (Table 1).

Operative Technique

Before surgery, identification of the vessels was made using a hand-held Doppler device (Bi-directional Doppler ES-100V3, Hadeco, Kawasaki, Japan). Additional information was obtained such as the velocity and the diameter of the perforator with a Duplex scan (Portable Ultrasound Device, LOGIQ-e BT11; General Electric, Conn.).

After complete debridement or resection of the wound or tumor, the dimension of the defect was determined by measuring the width, length, and depth. The propeller flaps were initially designed according to the defect volume based on the Doppler-traced perforator nearest to the margin of the defect. The design often extends the defect's width and length as the flap can be folded and stacked to obliterate the large dead space. After the anticipated design of the flap, a partial incision was made on the flap margin to identify the perforator under loupe magnification. A search for the pedicle was made with either a supra- or a subfascial approach. The viability of the perforator is determined by visually confirming a strong pulse. Once determined, a free-style approach was made by adjusting the design of the flap. During the elevation, the pedicle can be lengthened by dissecting the muscular portion and skeletonized to prevent kinking and maximize movement of the flap. The flap was elevated and totally deepithelialized and contoured to slightly overfit the dead space. The flap was rotated from 90 to 180 degrees according to the location of the defect and in some cases folded to obliterate death space completely. After the rotation, measurement of the velocity of the arterial and venous flow using a Duplex scan was performed before closure to be used as a reference for monitoring. The flap was then buried and closed primarily along with the donor site after placing the suction drains. The buried flap was monitored by Duplex scan postoperatively to observe the velocity of the pedicle and to determine the presence of fluid collection.

RESULTS

All flaps were based on a single perforator near the defect. The flap dimension ranged from $10 \times 5 \times 1$ to $15 \times 8 \times 2.5$ cm. The flaps were packed into the defect and were folded in 2 cases. The rotation arch of the flap ranged from 90 to 180 degrees. Primary closure and obliteration of dead space was successfully achieved in all flaps. The length of hospitalization for our department ranged between 4 and 13 days. The buried flaps were monitored

Table 1. The Outline of the Patients

Patient No.	Age	Sex	Prior Disease	Location of the Wound	Wound Dimension (cm)*	Flap Dimension (cm)*	Arch of Rotation (degrees)	Length of Stay (days)	Flap Survival	Follow-up (weeks)	Complications
1	63	M	Chordoma	Coccyx	10×7×10	15×8×2.5	150	21	Complete	160	Latent swelling and redness
2	31	M	Neurogenic tumor	Midline lower back	3×3×3	Folded 13×5×1	130	18	Complete	120	None
3	45	M	Schwannoma	Midline lower back	2×2×3	10×5×1	130	24	Complete	48	None
4	51	F	Burn	Right ischium	8×3×9	Folded 12×6×2	180	14	Complete	32	None
5	68	F	Lumbar degenerative kyphosis	Midline lower back	4×3×8	15×6×1.5	180	124	Complete	240	None
6	65	M	Metastatic follicular thyroid carcinoma	Midline upper back	5×8×11	8×18×1.5	90	15	Complete	36	None
7	39	M	Partial nephrectomy	Right flank	4×3×8	12×8×1.5	180	20	Complete	148	None

*The dimension is in length × width × depth.

by measuring the blood flow of the pedicle by Duplex scans. No immediate complications were noted such as seroma, hematoma, and wound dehiscence. Compression of the reconstructed site began on days 5–7. Donor sites healed without incidence. During the average follow-up of 28 months (range, 8 to 60 months), stable and reliable wound coverage was achieved in all patients with minimal donor site morbidity. However, 1 patient showed signs of latent redness and swelling over the flap at 7 months. The patient claimed that he fell down while exercising and felt a tear over the flap site. The patient was hospitalized and ultrasonogram showed no fluid collection. However, prophylactic broad-spectrum antibiotic and nonsteroidal antiinflammatory treatment was initiated and the signs regressed within 1 week (Table 1).

CASE REPORTS

Case 1

A 59-year-old man diagnosed with follicular thyroid carcinoma underwent oncologic resection of the spine due to metastasis by the orthopedic surgeon, leaving a defect of the upper back (Fig. 1A). The perforators were traced the day before surgery using Doppler near the anticipated re-

section site. Orthopedic surgery team removed 3 metastatic thoracic bones with extensive muscle excision while preserving the skin. Bone fixation was performed using plates and screws without dural complication. The suprafascial dissection was performed and perforator isolated. The pulsatile flow of the perforator was indicative of a reliable pedicle. Then an elliptical 8×18×1.5-cm–sized propeller flap was designed based on the perforator (inferolateral edge of the skin incision) to obliterate the defect of 5×8 × 11 cm (Fig. 1B). The flap was elevated, totally deepithelialized, and inset into the defect by a 90-degree clockwise rotation (Fig. 1C, D). After placement of suction drains, flap site and donor site were closed primarily. The buried flap was monitored using a Duplex scan. The velocity of the pedicle remained constant over the postoperative period. The patient started to ambulate on day 3, had the drains removed on day 8, and was discharged on day 11. There were no acute complications, and the patient at 9 months showed a well-healed and contoured posterior trunk (Fig. 2).

Case 2

A 39-year-old man diagnosed with schwannoma of the sacrum underwent total excision of the tumor with L5 total laminectomy and S1–3 sacrectomy, thus resulting in
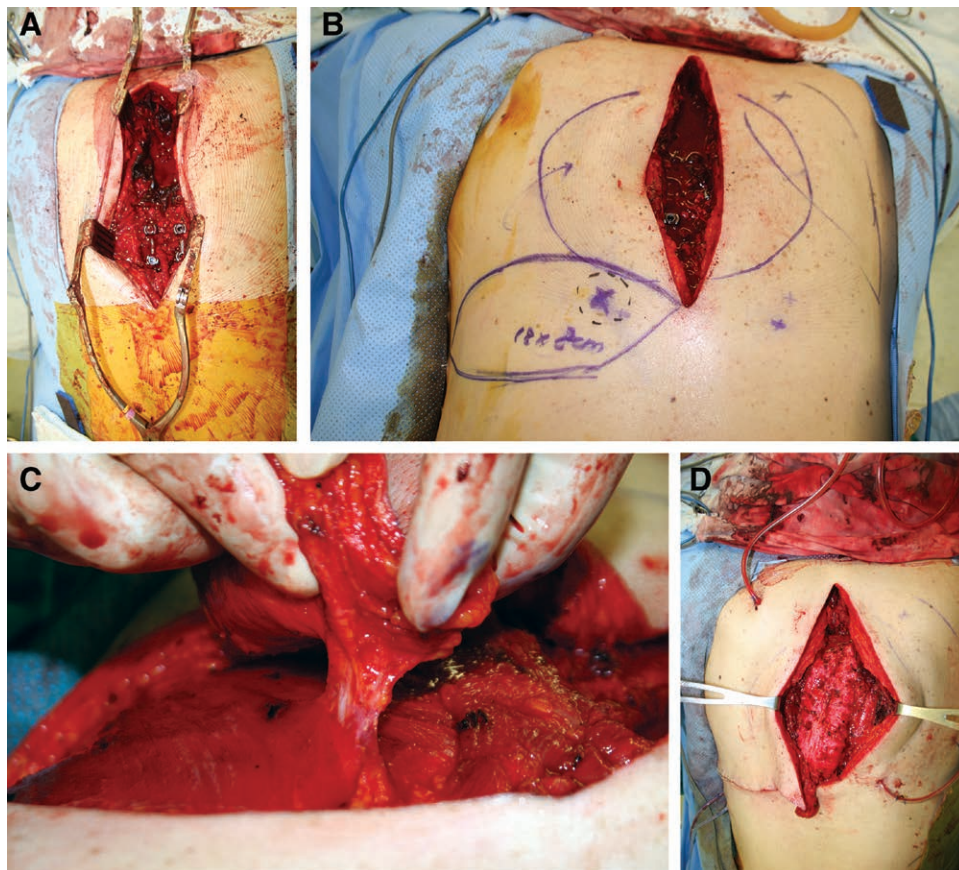

Fig. 1. A, A 5×8 × 11-cm defect of the back after removal of 3 metastatic thoracic bones and extensive muscle excision due to metastatic follicular thyroid cancer is presented. B, Flap was designed around the reliable perforator. C, D, An elliptical 8×18-cm-sized propeller flap with an 1.5-cm-thickness flap was elevated and then rotated 90 degrees clockwise based on a single perforator. After total deepithelialization of the flap, dead space was totally obliterated using this flap.

Fig. 2. Primary closure was achieved and healed without incidence. At 9 months after operation, minimal donor site morbidity is noted without recurrence.

a $2 \times 3 \times 3$ cm defect in the middle posterior trunk with the overlying skin intact (Fig. 3A). Based on preoperative tracing of the perforator and after identifying the perforator, an elliptical propeller flap with a dimension of $10 \times 5 \times 1$ cm was designed at the superolateral end of the skin incision. Flap was elevated suprafascially, totally deepithelialized, rotated 130 degrees clockwise, folded inward, and inset into the defect (Fig. 3B). The skin over the resection and the donor site were closed primarily. There were no acute complications related to the recipient and donor site. At 12 months, the patient showed a well-healed posterior trunk with good contour (Fig. 3C).

DISCUSSION

Wounds that undergo debridement due to wound complications frequently result in large dead spaces and exposure of hardware. Also, primary lesions such as cancer that need wide resection may end up with volume depletion after removal. In these wounds with large dead spaces, insufficient obliteration of the dead space permits congestion of blood or serum and may result in complications such as wound dehiscence, infection, and eventually operation failure.[1,7,9,13] In defects that result in formation

of large dead spaces, the reconstructive goal would be to obliterate the dead space with a well-vascularized tissue along with resurfacing over the defect. There can be many strategies involved with obliteration of dead spaces. One can close the wound with multiple quilting sutures and compression, or in smaller defects, one can advance the surrounding tissue to obliterate the dead space. However, providing optimal closure for posterior trunk defects with dead space can be challenging when the dead spaces are large, infected, or located in the middle of the posterior trunk.

Muscle flaps with or without skin paddles are the first line to reconstruct defects on the posterior trunk. But they have limits to obliterate defects that are large or located in the midtrunk requiring extended reach. The trapezius muscle flap is commonly used for the upper posterior trunk defects but with the drawbacks of short pedicle, lack of soft-tissue bulk, and possible functional morbidity.[1,2,8,13,14] For mid posterior trunk defects, latissimus dorsi and parasipinous (erector spinae) muscle flaps can be used. The latissimus dorsi muscle flap, especially in reserve pattern, has multiple advantages, where a segment can be harvested sparing muscle function and can be innervated by sensory nerves.[15–17] However, the latissimus dorsi muscle flap may have risk of insufficient volume and reduced blood supply in the distal part of the flap, and the paraspinous muscle is only suitable in spine patients with fusion in whom the muscle is no longer required for spinal stabilization or extension.[1,2,8,13,14,18] The gluteal muscle flap is useful to cover lower posterior trunk defects, and in larger defects, multiple muscle flaps may be used together to achieve satisfactory coverage but may result in significantly increased donor side morbidity.[1,2,5,10,13,14] Thus, to overcome these limits, we searched for a flap that provides larger bulk, better reach, and reliable vascular supply.

The concepts of perforator flaps, propeller flaps, and free-style approach have become popular in the microsurgical field. The basics for the perforator flaps formulated after Taylor and Palmer[8] showed that the branches of the cutaneous vessels radiate after piercing the deep fascia in all directions and interconnect to form a continuous vascular network. The use of various perforator flaps was then introduced.[9,12] But the use of perforator flaps as a versatile local flap came with Hyakusoku et al.[4] describing an adipocutaneous flap based on a adipofascial pedicle or a subcutaneous fat pedicle, designed like a propeller with 2 unequal blades that allow the long side to fill the defect. Subsequently, a skeletonized perforator pedicle-based fasciocutaneous flap with a 180-degree arch of rotation was presented by Hallock,[19] which allows to close donor side more easily. With further advancements and experience with perforator flaps, in 2004, Wei and Mardini[7] introduced the "free-style approach" that allows harvest of a flap in a free-style manner based only on the preoperative tracing of a perforator acquired by Doppler signals on a specific region. Using these concepts for reconstruction allows avoiding microsurgery for free flaps while achieving reasonable closure. The posterior trunk is no exception and reports have shown the efficacy of perforator-based local flaps to close complex and large posterior trunk de-
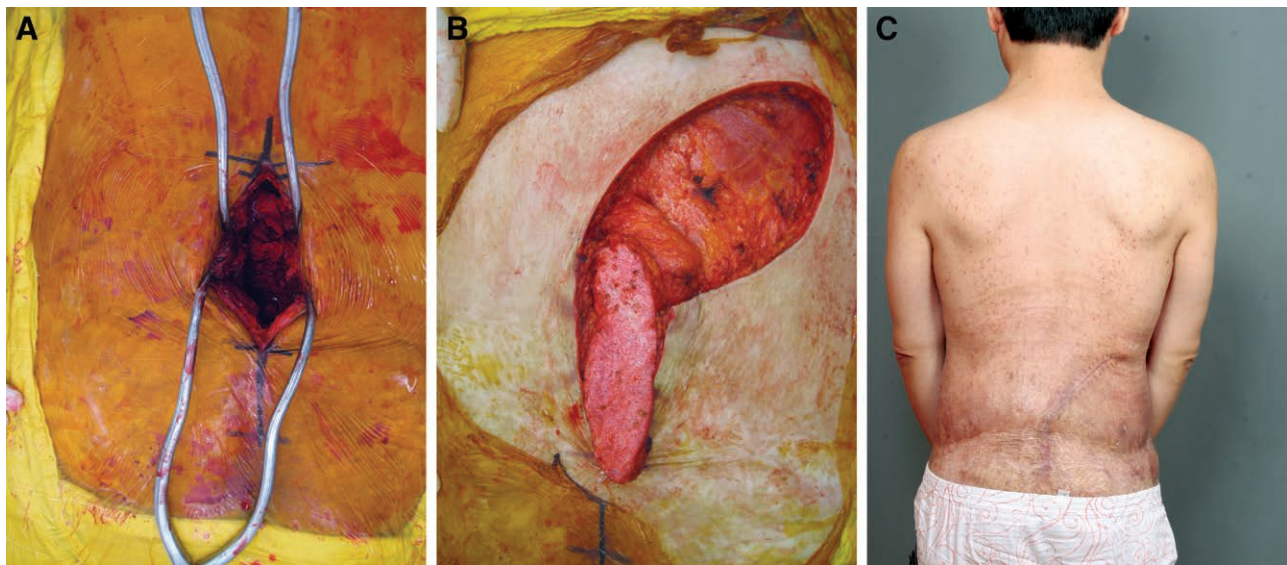
Fig. 3. A, L5 total laminectomy and S1–3 sacrectomy resulted in a 2 × 3 × 3-cm dead space in the middle posterior trunk. B, An elliptical propeller flap with a dimension of 10 × 5 × 1 cm was designed based on the perforator located near the upper margin of the defect. Based on this perforator, the flap was designed obliquely (about 2 o'clock from midline) to capture the horizontal linking vessels. Then, the flap was elevated suprafascially, totally deepithelialized, and rotated 130 degrees counterclockwise. C, Both defect site and donor site were closed primarily and healed without incidence. During 12 months of follow-up, stable and reliable wound coverage was achieved with minimal donor site morbidity.

fects.[10,20] We further explored the possibility of using this approach to not only resurface the wound but also obliterate the dead space.

We first started by partially deepithelializing the propeller flap that can accommodate the dead space and to resurface the defect. Deepithelializing part of the flap to obliterate dead space is not new. Using a random pedicled flap, Hill and Riaz[6] first described the deepithelialized gluteus maximus island flap to obliterate a cerebrospinal fluid (CSF) leak and Moon et al.[5] published a series of 13 cases of partially deepithelialized superior gluteal artery perforator flaps for small lumbosacral defects. We also use similar approaches when the defect is small and close to the recipient pedicle allowing the arc of rotation and advancement to reach the defect. However, when the defect is far from the recipient pedicle and requires large volume to obliterate dead space, this approach lacks the reach and the volume.

The approach using a perforator-based propeller flap allows a large skin flap to be harvested with adequate vascular supply and can supply a flap dimension up to 15 × 8 × 2.5 cm as shown in this series. The muscles are spared, minimizing donor site morbidity. There are few factors to consider when designing the flap. After identifying a pulsatile perforator, one should design the flap that allows the donor site to close primarily to achieve superior aesthetic outcome. The existence of multiple perforators around the defect allows having increased options for design. The flap design on the posterior trunk is usually made in a horizontal fashion to accommodate the axiality of the perforasome.[11] However, our experience shows that obliquely designed flaps have no circulation problems as shown in case 2. Now, we base the design not only on the axiality of the perforasome of the posterior trunk but also on the amount of rotation the flap will make. Thus, designs allowing less rotation are more favored. Another factor to consider is to design the flap volume larger than the defect to maximize obliteration. There are some technical considerations during elevation as well. During the elevation, it is important not to deepithelize too much of the skin paddle as the preservation of the dermis and subdermal plane will play an important role in linking the perforasomes.[11]

The midline defect often involves exposure of spine and hardware. After neurosurgical procedures, the rates of postoperative infection of the wound still vary from 1% to 16%.[21,22] Risk factors for wound infection after neurosurgery are CSF leak, foreign body, repeated surgery, or operations lasting more than 4 hours. Hence, if a dead space is expected or if there is a risk for CSF leak or instrumentation exposure, a tight and bulky flap must be used to obliterate the dead space. Although there have been debates over the superiority of vascularity of muscles over skin flaps to fight infection, recent trend has been focused on adequate debridement and coverage with perforator flaps.[23–26] Using perforator flaps has shown to be feasible with good outcome as using muscle flaps. The debate on how much a single perforator can supply the skin flap still remains to be solved. Multiple factors are considered to have a viable flap, but ideally, if the skin flap has more than 2 or 3 angiosome territories, it would be wise to consider using more than 1 flap to achieve the goal. The deepithelialized flaps can be stacked into double layers if a single layer of adipocutaneous flap is not enough. If the defect requires more coverage, more than 1 perforator flap can also be used to accommodate the large defect.[20] Nevertheless, a single perforator-based flap can cover defects of up to 700 cm³ as shown in this series while still

obtaining primary closure. The postoperative monitoring can be done using a Duplex scan to measure the velocity of the artery and vein of the pedicle. Another advantage in using ultrasound technology is to see if there is any unwanted fluid collection underneath the skin. Another option for monitoring would be to leave a small island of skin that can be removed at a later date. We start compressing the reconstructed site on day 7 with bandages or garments to further obliterate dead space or to minimize any fluid collection. This approach has shown to be effective to minimize shearing to obtain stable closure and to ambulate early.

The indication for this procedure is large 3-dimensional wounds with or without skin defect, where conventional flaps are difficult to reach or cannot provide adequate volume. This series focused on large extensive wounds that required full deepithelialized propeller flaps on the midline posterior trunk and demonstrates the efficacy of this approach. With accurate design and free-style approach, these flaps can be used for dead space management.

CONCLUSION

In large-volume defects on the posterior trunk, where conventional flaps may lack volume and reach, the use of deepithelialized propeller flap can provide adequate bulk and vascularity to successfully reconstruct the defects with minimal donor site morbidity.

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