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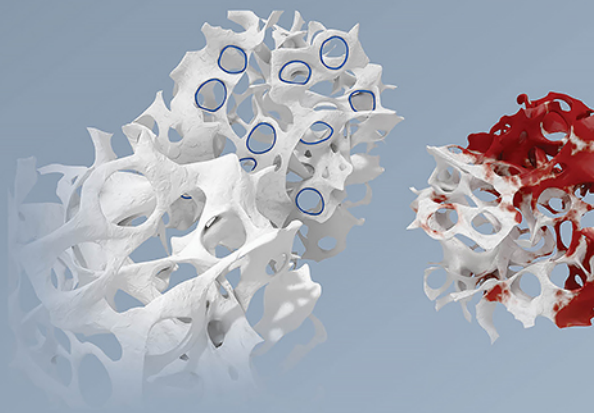

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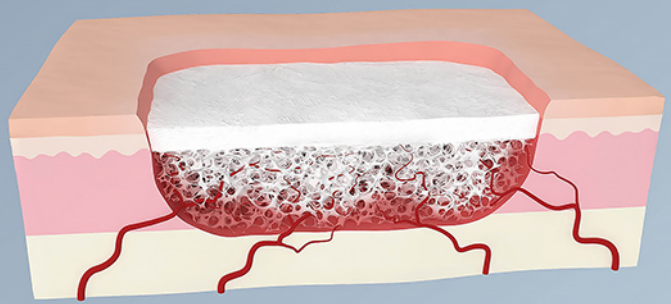

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ORIGINAL ARTICLE

A simple concept for covering pressure sores: wound edge-based propeller perforator flap*

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Key words
Perforator flap; Pressure sore; Propeller; Wound edge

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Abstract

We present a new surgical modification to allow propeller perforator flaps to cover pressure sores at various locations. We used a propeller perforator flap concept based on the detection of newly formed perforator vessels located 1 cm from the wound margin and stimulated by the chronic inflammation process.

Between January 2009 and January 2017, 33 wound edge-based propeller perforator flaps were used to cover pressure sores at various locations in 28 patients. In four cases more than one flap was used on the same patient. The patients comprised 18 males and 10 females with a mean age of 41·25 (range, 16–70) years.

All patients underwent follow-up for 0–12 months. The mean follow-up duration was 5·03 months. Venous congestion was observed in three flaps that were rotated by 180° (9·1%). However, there was a significant difference between flaps rotated by 90° and 180° according to the complication rate ($P = 0{\cdot}034$). Out of 33 flaps, 29 flaps healed uneventfully. Patients were able to sit and lie on their flaps three weeks after surgery.

In our study, we were able to obtain satisfying final results using these novel flaps.

Introduction

Perforator flaps were first described in plastic surgery literature by Koshima and Soeda in 1989. (1) However, the 'free-style flaps' described by Asko-Seljavaara in 1983 and the 'angiosome concept' of Taylor proposed in 1987 can be interpreted as predecessors of the term 'perforator flap'. (2) The popularity of perforator flaps has increased gradually in recent years, and today, such flaps have become reliable reconstructive options. (3) The propeller flap concept was first described by Hyakusoku *et al.* in 1991. (4) The term 'propeller perforator flap' was first used in the coverage of ischial and trochanteric pressure sores by Hallock in 2006. (5) It was subsequently demonstrated that propeller perforator flaps could be designed using a single pedicle, allowing an increase in size and the ability to be rotated by angles of up to 180°. (6) Propeller perforator flaps can be used as safely as regular perforator flaps.

*Particularly presented at 4th Amiens Perforator Flap Meeting 4–6 June 2015 in France and 7th EPSRC Meeting 27–30 August 2015 in Hamburg/Germany.

Key Messages

- there were challenging conditions for plastic surgeons because of the limited flap options and high rate of recurrence
- the aim of this study was to present a new surgical modification of the propeller perforator flap for covering pressure sores
- a total of 33 flaps were performed in 28 patients.
- venous congestion was seen in three flaps; we faced one total flap loss and one particular flap loss, and 29 flaps healed uneventfully
- this novel technique may prove to be another reliable and easy reconstruction method

Table 1 Patients' characteristics

Number of patients	28 (10 female, 18 male)
Number of flaps	33
Age (years)	41·25 (16–70)
Defect size (cm^2)	42·5 (20–135)
De-epithelialisation	11% (36)
Venous congestion	3% (9·1)
Total flap loss	1% (3)
Particular flap loss	1% (3)
Wound dehiscence	1% (3)
Follow-up (months)	5·03 (0–12)

Pressure sores provide challenging conditions for plastic surgeons because of the limited flap options and high rate of recurrence. (7) Thus, when choosing a flap, the possibility of a future reconstructive procedure should be borne in mind. (8) In light of this, the use of perforator flaps to cover pressure sores has recently gained popularity.

In this study, we present a new surgical modification of the propeller perforator flap that enables pressure sores to be covered at various locations. Although the technique is based on the propeller flap concept, it takes its basis from newly formed perforators located at the wound edge that are induced by the chronic inflammation process.

Patients and methods

Between January 2009 and January 2017, 33 wound edge-based propeller perforator flaps were used to cover chronic pressure sores at various locations in 28 patients. In four cases, more than one flap was used on the same patient. The patients comprised 18 males and 10 females with a mean age of 41·25 (range: 16–70) years, and all were paraplegic. All pressure sores were classified as grades III and IV according to the classification of Shea. (9) There were 9 ischial, 10 sacral, 8 trochanteric, 5 gluteal and 1 knee pressure sores in this patient series, and the defect sizes ranged from 4 × 5 cm to 15 × 9 cm. Patients' characteristics are given in Table 1.

Surgical technique

Patients were placed on the operating table according to the location of the sore. At least one perforator was then detected with an 8 mHz hand Doppler probe (Huntleigh Multi Dopplex II; HNE Diagnostics, Cardiff, UK) within 1 cm of the wound margin (Figure 1A). Haemostasis was performed after adequate sore debridement and bony prominence reduction. Then, the flap skin island was designed with either an elliptical or semi-elliptical propeller shape; the design was based on the Doppler image of the perforator and in accordance with the potential for tissue mobilisation and skin lines, taking care to minimise donor site morbidity and allow for future surgical options. After the skin was marked, flap harvesting began from the most distal portion according to the defect. A suprafascial dissection was then performed. Before dissecting the wound margin, a preoperative re-evaluation of the perforator was undertaken. The perforator was not preferentially skeletonised, and a 0·5-cm diameter subcutaneous pedicle, including the perforator, was preserved as long as it allowed for the easy

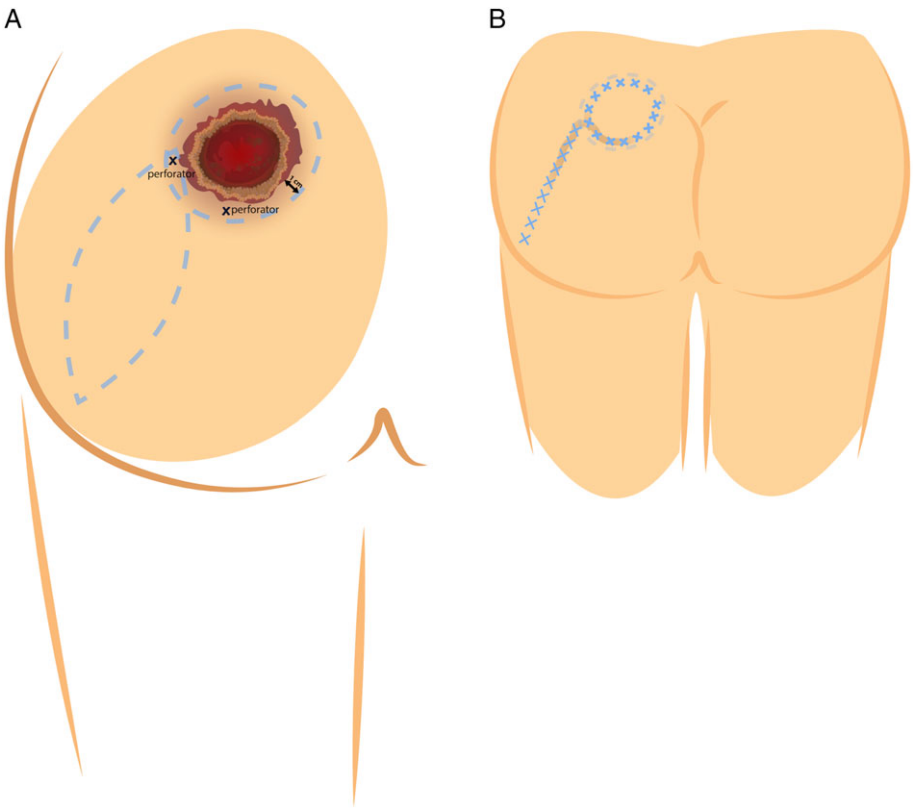

Figure 1 Showing: (A) Illustration of a pressure sore in the left gluteal region, location of the perforator (x indicates the perforator) around the wound margin and the flap design with an elliptical, acentric propeller shape. (B) Closure of the donor site at the end of the operation.

Table 2 The twisting angles and defect areas

	Defect area					
Twisting angle	Sacral	Trochanteric	Ischial	Knee	Gluteal	Total
90°	8	1	6	1	3	19
180°	2	7	3	0	2	14
Total	10	8	9	1	5	33

rotation/transposition of the skin flap without tension or constriction. If necessary, part of the flap was de-epithelialised to obliterate dead space. A low-suction drain was placed under the flap, and the donor site was closed (Figure 1B).

Statistical analysis

Comparisons of performance endpoints between groups were performed using the Chi-squared test appropriately for categorical variables, whereas the Mann–Whitney *U*-test was used for continuous variables. *P* values $< 0{\cdot}05$ were considered significant. Statistical analysis was performed using SPSS statistics version 20 (SPSS Inc., Chicago, IL).

Results

All patients underwent a follow-up for a period of 0–12 months, and the mean follow-up duration was 5·03 months. One patient died owing to general medical problems 2 days after surgery. Venous congestion was observed in three flaps that were rotated by 180° (9·1%). However, there was a significant difference between flaps rotated by 90° and 180° according to the rate of complications ($P = 0{\cdot}034$). One flap necrosed completely within 2 days after surgery (3%). This patient's defect was reconstructed with a gluteal rotation flap. In another patient, the flap survived only partially. One flap eventually survived completely but only after leech therapy. In a patient diagnosed with Ewing sarcoma, the occurrence of wound dehiscence was seen probably due to the use of chemotherapeutic agents 4 weeks after surgery (3%). De-epithelialisation of the skin to fill dead space was performed in 11 flaps (36%). Of those 11 flaps, 7 flaps (63·6%) were used in the ischial region.

The twisting angles of the flaps ranged between 90° and 180° (Table 2). Out of 10 flaps in the sacral region, 8 had a twisting angle of 90°. One flap with a rotation angle of 180° was found to be totally necrosed in the sacral region. However, seven out of eight flaps in the trochanteric region had a twisting angle of 180°. In this region, venous congestion was observed in one case; the flap was treated with leech therapy and survived completely. Of a total of 33 flaps, 29 flaps healed uneventfully. Patients were able to sit and lie on their flaps 3 weeks after surgery.

Case reports

Case 4

A 37-year-old paraplegic woman presented with a pressure sore ulcer of around 5×7 cm in size, with some undermining in her left gluteal region (Figure 2A). She was followed up for wound management at a different centre and was referred for reconstruction. The patient was in good general condition with no systemic contraindication for surgery. After debridement, a wound edge-based propeller perforator flap (WEBPPF) was planned and raised for reconstruction, as indicated above. De-epithelialisation was performed to fill dead space (Figure 2B). The twisting angle of the flap was 180°. The

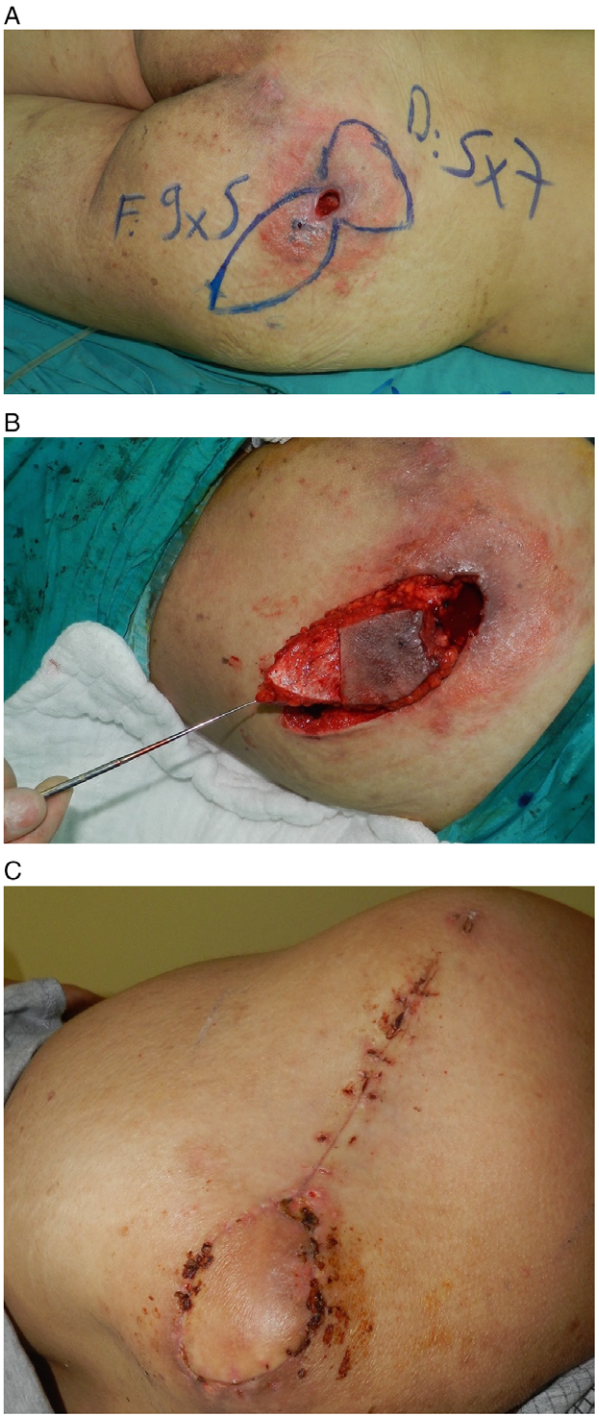

Figure 2 Showing: (A) The preoperative dimensions of the defect and flap. (B) De-epithelialisation performed on the distal part of the flap. (C) A view of the flap at 1 month after the operation.

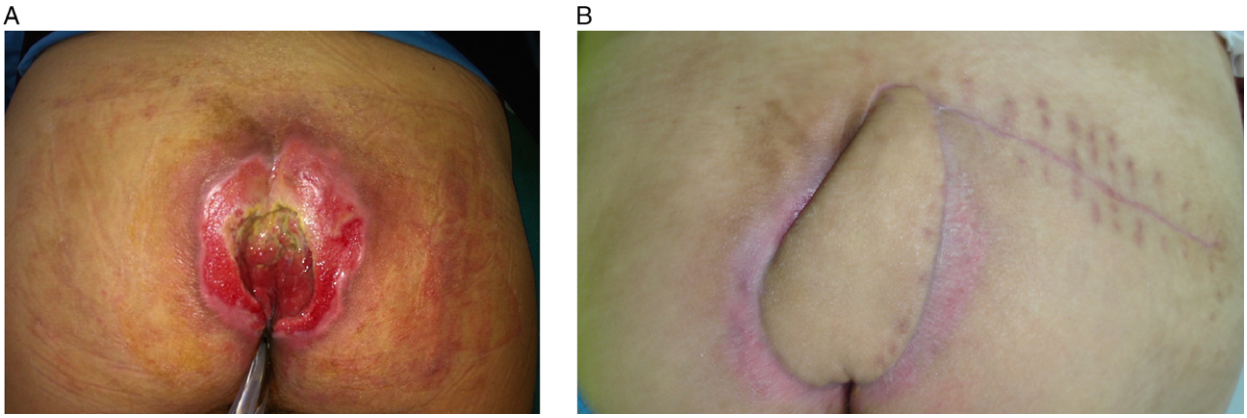

Figure 3 Showing: (A) A view of the pressure sore in the sacral region. (B) A view of the flap at 9 months after the operation.

patient was discharged on the seventh postoperative day, and no complications were observed. Three weeks after surgery, she was allowed to sit or lie on her flap. At the 1-month follow-up visit, the flap was stable, and the wound had healed uneventfully (Figure 2C).

Case 8

A 53-year-old paraplegic woman presented with a 4-month-old sacral grade III–IV pressure sore (11 × 8 cm) (Figure 3A). She was referred to our centre 1 month after initial wound management and was in good general condition with no contraindication for surgery. After debridement, a WEBPPF was planned and raised for reconstruction, as indicated above. The twisting angle of the flap was 90°. The patient was discharged on the seventh postoperative day. No complication occurred, and the wound healed uneventfully. Three weeks after surgery, the patient was allowed to sit or lie on her flap. At the 9-month follow-up visit, the flap was stable, and there was no recurrence or ulceration (Figure 3B).

Case 25

A 35-year-old paraplegic man presented with a pressure sore ulcer of about 8 × 5 cm in size in his left gluteal region (Figure 4A). He was followed up for wound management at a different centre and was referred for reconstruction. The patient was in good general condition with no systemic contraindication for surgery. In the same session, debridement was performed, and a WEBPPF was raised for reconstruction, as indicated above. The flap was rotated on the defect site (Video 2), and the donor site was closed (Figure 4B). The twisting angle of the flap was 90°. The patient was discharged on the seventh postoperative day, and no complication was observed. Three weeks after surgery, he was allowed to sit or lie on his flap. At the 6-month follow-up visit, the flap was stable, and the wound had healed uneventfully (Figure 4C).

Discussion

The reconstruction of pressure sores provides a challenge for plastic surgeons due to the limited reconstruction options and high rates of recurrence. Particular treatment modalities may be chosen according to the patients' general health, keeping in mind the possibility of recurrence. In pressure sores that are associated with an aged population with multi-system disorders, conservative treatment, including wound dressings, may be the first choice. On the other hand, in a younger population or those incurring pressure ulcers due to paraplegia or trauma, reconstructive options should be considered, and the possibility of future reconstructive procedures should be borne in mind. Although traditional flap choices such as musculocutaneous and fasciocutaneous flap techniques are commonly used, perforator flaps have gained popularity among reconstructive surgeons, starting with the perforator flap model performed for the treatment of sacral pressure sores by Koshima *et al.* (10) The popularity of perforator flaps has increased gradually in recent years, and today, such flaps have become reliable reconstructive options. (3) The flaps reduce donor field morbidity by preserving muscle, nerves and the deep fascia (11) and can be used either as pedicled flaps or as free flaps. (12) Flap design, size and content can vary greatly, depending on the donor and recipient areas. (3) In essence, it should be possible to create a flap wherever a cutaneous perforator is located. (13) Pedicled perforator flaps allow defects to be covered with the most appropriate tissue in terms of the composition, shape and location of the defect. (14) A number of studies concerning the covering of pressure sores with perforator flaps have shown that they are a reliable treatment modality.(7,8,10,13–17)

The propeller flap concept was described by Hyakusoku *et al.* in 1991. (4) The term 'propeller perforator flap' was first used in the coverage of ischial and trochanteric pressure sores by Hallock in 2006. (5) At this time, it was shown that large-sized propeller perforator flaps could be designed using a single perforator and rotated by up to 180°. (6) These flaps can be used as safely as regular perforator flaps. Although they were initially described for pressure sore reconstruction and mainly suggested for extremity reconstruction, they can also be used in various locations. (18) With regards to pressure sores, these flaps have the advantage of being reliable, reducing the operative time and being easy to perform, along with reducing donor site morbidity.(5,19–21)

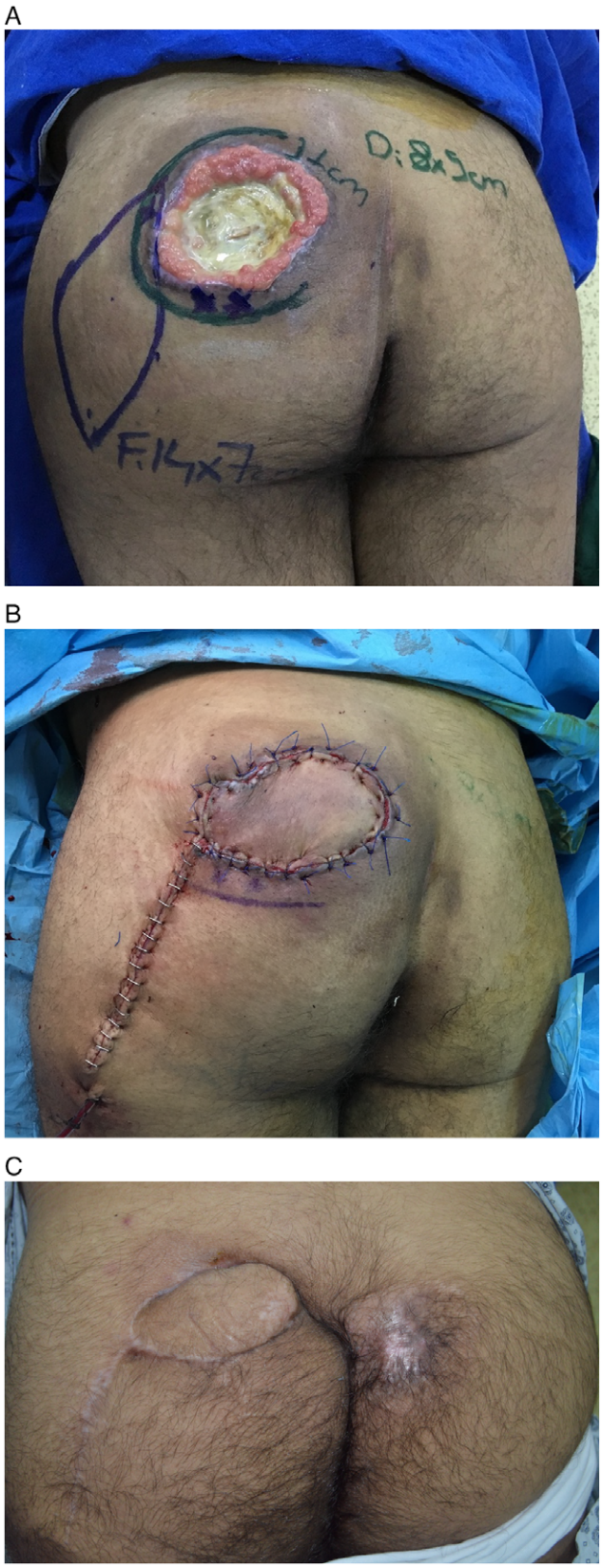

Figure 4 Showing: (A) The preoperative dimensions of the defect and flap and the location of the perforator around the wound margin. (B) A view of the immediate postoperative result. (C) A view of the flap at 6 months after the operation.

In this study, we used the propeller perforator flap model based on newly formed or enlarged perforators located in the chronic wound edge, rather than those based on anatomically well-defined source vessels. Different from the standardised perforator flap concept, we made no particular effort to skeletonise the perforator. A circa 0·5 cm diameter subcutaneous pedicle around the perforator was preserved to allow the flap to be rotated into the defect region. As we did not dissect the vessel until its source artery, we chose to call this method the 'wound edge-based propeller perforator' flap or WEBPPF. Although perforator flaps are known to reduce donor site morbidity, classical intramuscular perforator dissection may not allow the use of that muscle as a secondary reconstruction option. WEBPPFs, however, are raised without intramuscular perforator dissection, which enables the underlying muscle to be used if a secondary intervention appears necessary.

Similar to Hyakusoku *et al.*'s work (22), WEBPPFs have an acentric design but differ from Hyakusoku's work (22) in that perforators are detected at the wound edge. This modification allows us to eliminate the requirement to skeletonise the perforator and the need for microsurgical dissection techniques and enables the flaps to be easily rotated to the defect site. As we have shown, large-sized WEBPPFs can be designed safely, although the absolute maximum size of such a flap has yet to be clearly defined. This leaves us with the peculiarity that skin flaps can be designed on perforators that, probably, develop in the wound edge due to chronic inflammation and an attempt at wound healing.

On the other hand, as a strong stimulator of neoangiogenesis (23), abundant levels of VEGF may be a reasonable explanation for the presence of relatively high-calibre perforators bordering wound margins. Levels of vascular endothelial growth factor (VEGF) have been already shown to be elevated in pressure sore wound margins. (23) Previous studies have described the main effect of VEGF as vasculogenesis and angiogenesis. (24) In our study, we were able to obtain satisfying final results using WEBPPFs based on these newly formed or high-calibre perforators due to elevated VEGF levels. However, it is difficult to screen patients for perforators before they have developed an ulcer; we presume, therefore, that these perforators are not present when the ulcer forms.

Our series included three patients who experienced venous congestion. This was considered to be due to the twisting of the subcutaneous pedicle because veins are more prone to the harmful effects of torsion than arteries. Thus, the venous insufficiency rate may be high with any of the propeller flap models. The twist angle of these three flaps was 180°. Of these flaps, one flap became completely necrotic, one flap healed partially, and the remaining flap was treated with leech therapy and healed completely. However, we did not detect any total or particular necrosis when the twist was 90°. Our work showed that there was a significant difference between flaps twisted at angles of 90° and 180° according to the complication rate ($P = 0{\cdot}034$).

De-epithelialisation was performed in 11 flaps (36%), showing that it is possible to use the distal part of the flap to obliterate dead space. (25)

Conclusion

In the treatment of chronic pressure ulcers, WEBPPFs proved to be another reliable and easy reconstruction method, leaving open the option of other treatment modalities in the future.

Acknowledgments

The authors declare that they have no conflicts of interest to disclose.

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