The Utility and Versatility of Perforator-Based Propeller Flaps in Burn Care

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The majority of surgical burn care involves the use of skin grafts. However, there are cases when flaps are required or provide superior outcomes both in the acute setting and for postburn reconstruction. Rarely discussed in the context of burn care, the perforator-based propeller flap is an important option to consider. We describe our experience with perforator-based propeller flaps in the acute and reconstructive phases of burn care. We reviewed demographics, indications, operative details, and outcomes for patients whose burn care included the use of a perforator-based propeller flap at our institution from May 2007 to April 2015. Details of the surgical technique and individual cases are also discussed. Twenty-one perforator-based propeller flaps were used in the care of 17 burn patients. Six flaps (29%) were used in the acute phase for coverage of exposed joints, tendons, cartilage, and bone; coverage of open wounds; and preservation of range of motion (ROM) by minimizing scar contracture. Fifteen flaps (71%) were used for reconstruction of postburn deformities including coverage of chronic wounds, for coverage after scar contracture release, and to improve ROM. The majority of flaps (94% at follow-up) exhibited stable soft tissue coverage and good or improved ROM of adjacent joints. Three cases of partial flap loss and one case of total flap loss occurred. Perforator-based propeller flaps provide reliable vascularized soft tissue for coverage of vital structures and wounds, contracture release, and preservation of ROM across joints. Despite a relatively significant risk of minor complications particularly in the coverage of chronic wounds, our study supports their utility in both the acute and reconstructive phases of burn care. (J Burn Care Res 2017;38:20–27)

Surgical burn care involves the use of autologous skin grafting for closure of deep burn wounds in most cases. Skin grafts provide effective coverage for a variety of burn defects and can be harvested easily and expediently. However, there are instances when the use of vascularized tissue transfer (ie, flap) is required or would provide for a superior outcome, both in the acute setting and for postburn reconstruction.[1,2] A hypovascular or inhospitable recipient site may preclude graft take, for example, and therefore require a flap for closure. Flaps are preferable for the coverage of vital structures and across joints because they allow for early mobilization and are less prone to secondary contraction. In postburn reconstruction, vascularized tissue is often necessary for resurfacing after scar contracture release. Additionally, on the face, flaps can preserve aesthetic units and provide a superior aesthetic outcome. Indeed, an optimal approach for burn reconstruction is the use of adjacent or regional skin flaps to minimize differences in skin characteristics.

Despite the benefits, the use of flaps is often limited in burn treatment, for a multitude of reasons, especially in the case of extensive burns, where expeditious wound closure is a priority. This is further complicated by a paucity of available healthy tissue available for transfer in extensive burn injuries. In

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Presented at the American Burn Association 48th Annual Meeting, Las Vegas, NV, May 2016.

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Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site.

1559-047X/2016

DOI: 10.1097/BCR.0000000000000447

cases where a flap is required, but local flaps are not available, then regional, distant, or free microvascular tissue transfers may be required.

The perforator-based propeller flap is a versatile option in reconstructive surgery.[3–7] However, there is sparse literature describing its use in burn reconstruction. In addition, reports that describe flap use in burn care tend to focus on the reconstruction of postburn sequelae but do not address acute burn treatment. The purpose of the current study is to report on our experience using perforator-based propeller flaps during the acute and reconstructive phases of burn care. We also describe the surgical technique employed and present individual cases in an effort to increase awareness of this option in the care of burn patients.

METHODS

The records of patients whose burn care included the use of a perforator-based propeller flap at our institution from May 2007 to April 2015 were retrospectively reviewed. Patients of all ages were eligible for inclusion. The study was approved by the institutional review board at our institution, and the research described herein was conducted in accordance with the ethical guidelines set forth by this committee.

Burn patients were included in the study if a perforator-based propeller flap was used in the acute phase of burn care (ie, during the hospitalization period immediately after the burn injury) or for postburn reconstruction. The decision to use a perforator-based propeller flap was made on a case-by-case basis by the senior surgeon (L.J.G.) after assessment of the injury and needs of the patient. Collected information included patient demographics, mechanism and location of burn injury, phase of burn care (acute vs reconstructive), and indication for perforator-based propeller flap reconstruction. Additionally, flap location, source vessel, surgical complications, the need for additional procedures, and long-term outcomes were reviewed.

Operative Technique

A standard hand-held 8- to 10-MHz Doppler ultrasound probe was used to identify perforating vessels near the defect. Before incision, the flap was preliminarily designed and marked taking into account the size of the defect and the location of the audible perforator(s) within the prospective donor area. The procedures were performed under 3.5× loupe magnification.

An initial incision was made to allow for direct visualization of the perforator(s). Dissection was performed in the supra- or subfascial plane. If the perforator(s) was deemed an appropriate option (ie, based on pedicle size and distance from the defect), markings were finalized. Perforators of flaps that need to rotate more than 90° were skeletonized to minimize kinking or torqueing of the associated veins by the subcutaneous tissue. Additional length of the perforating vessel(s) was frequently obtained by subfascial and occasionally intramuscular dissection down to the source vessel. After adequate dissection of the perforating vessel(s), the design of the flap was finalized and the rest of the flap was incised and elevated. The flap was then rotated or transposed into the recipient site. Donor sites were either closed primarily or with a skin graft. Postoperatively, operative sites were loosely wrapped with soft bandages and extremities were elevated. If the flap was located across a joint, the joint was immobilized with a splint for approximately 1 week, after which physical and/or occupational therapy was initiated.

RESULTS

From May 2007 to April 2015, 21 perforator-based propeller flaps were used in the care of 17 burn patients. Two patients required two perforator-based propeller flaps, and one patient required three. Patient characteristics and mechanism of burn injury are listed in Table 1. All flaps in this study were performed on extremities. Thirteen flaps (62%) were used for the reconstruction of lower extremity injuries, and eight flaps (38%) were used for the

Table 1. Patient characteristics

No. of patients	17
Male/female	13/4
No. of flaps*	21
Mean age (year)	19 (range, 2–56)
Mechanism of burn injury	
Scald	7
Thermal	4
Contact	3
Flame	2
Friction	1
Mean TBSA burn (%)	25.4 (range, 2–98)
Mean TBSA covered (%)†	2.4 (range, 0.5–5)
Location of burn requiring flap	
Lower extremity (%)	13 (62%)
Upper extremity (%)	8 (38%)

*One patient received three perforator-based propeller flaps and two patients received two during the course of their burn care.
†Area resurfaced with a propeller flap.

Table 2. Perforator-based propeller flaps used in the acute phase of burn care

Location of Injury	Location of Flap	Indication for Flap use	Source Vessel (Artery)
Left thumb	Volar forearm	Coverage of exposed MCP joint capsule; preservation of ROM	Radial
Left thumb	Dorsal thumb	Coverage of exposed tendon; preservation of ROM	Princeps pollicis
Right dorsal hand	Dorsal hand	Coverage of exposed MCP joint capsule, tendon, and cartilage	Radial digital artery to little finger
Left second toe	Dorsal foot	Coverage of exposed bone and joint; preservation of ROM	Medial digital artery to second toe
Left dorsal foot	Anterior aspect of lower leg	Coverage of open wound and exposed tendons	Peroneal
Right tibia	Tibialis posterior muscle	Coverage of exposed bone	Posterior tibial

MCP, metacarpophalangeal; *ROM*, range of motion.

reconstruction of upper extremity injuries. One patient suffered a burn injury to the axilla, which was categorized as an upper extremity injury. Fifteen flaps (71%) were used for reconstruction of postburn deformities, and six flaps (29%) were used in the acute phase of burn care.

Table 2 details the perforator-based propeller flaps used for acute burn wounds. Indications for flap use after an acute burn injury included coverage of exposed joints, tendons, cartilage, and bone; coverage of open wounds; and preservation of range of motion. Five of the six flaps (83%) used for acute burn injuries demonstrated no immediate postoperative complications. One flap (17%) was lost because of vascular compromise of the pedicle related to inadequate venous drainage. This required return to the operating room for debridement and skin graft coverage. The five surviving flaps provided stable soft tissue coverage over exposed vital structures and preserved range of motion of adjacent joints after surgery during the hospitalization. One patient (case 1, see below) demonstrated stable coverage and preserved range of motion at 89-month follow-up. Another patient (case 2, see below) also demonstrated stable coverage and preserved range of motion at 3-month follow-up. Three patients in the acute group were lost to follow-up within the first few months postoperatively, and data on long-term outcomes are unavailable.

Table 3 details the perforator-based propeller flaps used for postburn reconstruction. Indications for flap use in this group included coverage of chronic wounds or coverage after burn scar contracture release. The majority of flaps (80%) used for reconstruction of postburn sequelae were not associated with postoperative complications. Three flaps (20%) sustained partial flap loss at the distal tip of the flap. None of these required operative intervention, and these small areas healed by secondary intention. All 15 flaps in this group demonstrated stable soft tissue

Table 3. Perforator-based propeller flaps used for postburn reconstruction

Location of Injury	Location of Flap	Indication for Flap Use	Source Vessel (Artery)
Left axilla	Upper arm	Contracture release; preservation of ROM	Superior ulnar collateral
Left elbow	Upper arm	Contracture release; preservation of ROM	Posterior radial collateral
Right elbow	Upper arm	Contracture release; preservation of ROM	Radial recurrent
Right wrist	Volar forearm	Contracture release; preservation of ROM	Radial
Right wrist	Volar forearm	Contracture release; preservation of ROM	Radial
Left knee	Medial thigh	Contracture release; preservation of ROM	Descending genicular
Left knee	Lateral thigh	Contracture release; preservation of ROM	Descending branch of LFC
Left dorsal foot	Dorsal foot	Contracture release; preservation of ROM	Dorsalis pedis
Left dorsal foot	Dorsal foot	Contracture release; preservation of ROM	Fourth dorsal metatarsal
Right knee	Lateral thigh	Contracture release; preservation of ROM	Descending branch of LFC
Right knee	Lateral thigh	Contracture release; preservation of ROM	Descending branch of LFC
Right knee	Lateral thigh	Coverage of chronic wound and contracture release	Descending branch of LFC
Right lower leg	Lower leg	Coverage of chronic wound	Peroneal
Right dorsal foot	Dorsal foot	Contracture release; preservation of ROM	Dorsalis pedis
Right dorsal foot	Dorsal foot	Contracture release; preservation of ROM	Fourth dorsal metatarsal

LFC, lateral femoral circumflex; *ROM*, range of motion.

Table 4. Source vessels to propeller flaps

Source Vessel	No. of Patients
Descending branch of the LFCA	4
Radial artery	3
Peroneal artery	2
Dorsalis pedis artery	2
Fourth dorsal metatarsal artery	2
Radial digital artery to little finger	1
Medial digital artery to second toe	1
Descending genicular artery	1
Superior ulnar collateral artery	1
Posterior radial collateral artery	1
Posterior tibial artery	1
Princeps pollicis artery	1
Radial recurrent artery	1

LFCA, lateral femoral circumflex artery.

coverage and improved range of motion of adjacent joints at follow-up (range 2 to 99 months).

With respect to the vascular supply to the flaps, 13 distinct source vessels were used (Table 4). Perforators were based off of the descending branch of the lateral femoral circumflex artery (n = 4), the radial artery (n = 3), the peroneal artery (n = 2), the dorsalis pedis artery (n = 2), the fourth dorsal metatarsal artery (n = 2), the radial digital artery to the little finger (n = 1), the medial digital artery to the second toe (n = 1), the descending genicular artery (n = 1), the superior ulnar collateral artery (n = 1), the posterior radial collateral artery (n = 1), the posterior tibial artery (n = 1), the princeps pollicis artery (n = 1), and the radial recurrent artery (n = 1).

Finally, a significant number of patients in our study suffered extensive burns that affected the majority of their body. It was therefore impossible in many cases to harvest a flap from tissue that had not been injured during the burn. To that end, eight flaps that were used for the reconstruction of postburn deformities were elevated from an area that had been burned and subsequently skin grafted and one flap was elevated from an area of healed partial thickness skin. In these cases, the development of chronic wounds, burn scar contracture, and/or secondary skin graft contraction necessitated additional treatment with a flap. The majority of these flaps provided adequate and stable coverage and were not associated with complications. However, the three cases of partial flap loss were part of this group. Despite this, these flaps provided stable coverage and/or improved range of motion at long-term follow-up.

Case 1

A 50-year-old man sustained a 60% TBSA burn after exposure to molten metal. Skin grafts were used to resurface the majority of his wounds. However, a full-thickness wound of the left hand over the lateral thumb, thenar eminence, and palm required debridement of skin, subcutaneous tissue, and muscle. The residual wound would not support a skin graft (Figure 1A). Therefore, during his initial hospitalization, a radial artery propeller flap, based on a distal perforator (ie, septocutaneous vessel) or the radial artery, was used to close the wound (Figure 1B, C). Venous drainage was through the veins accompanying the perforating artery. Of note, the radial artery was preserved as the flap was based off perforating vessels. The flap was transposed 180° to fit into the defect (Figure 1D, E, see Supplementary Video, Supplemental Digital Content 1, http://links.lww.com/BCR/A84). The donor site was closed with

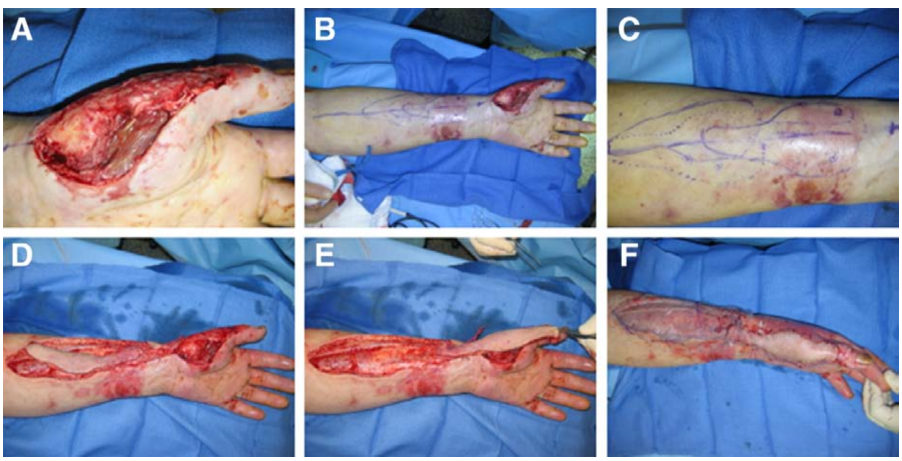

Figure 1. A. Full-thickness wound over the lateral thumb, thenar eminence, and palm, with exposed muscle tissue. B, C. Propeller flap designed based on radial artery perforator. D, E. Flap was transposed 180° to fit the defect. F. Donor area was closed with split-thickness skin graft.

Figure 2. Result at 89-month follow-up. Donor and recipient sites are well healed and range of motion is preserved.

split-thickness skin graft (Figure 1F). Follow-up at 89 months revealed that the area was well healed, demonstrating the durability of this flap over time when used in the acute setting (Figure 2, see Supplementary Video, Supplemental Digital Content 2, http://links.lww.com/BCR/A85).

Case 2

A 32-year-old man with a past medical history of diabetes and chronic kidney disease presented with extensive friction burn injury and road rash to his bilateral upper and lower extremities after a motorcycle accident. He was brought to the operating room initially for debridement of necrotic tissue. On hospital day 9, he returned to the operating room for second-stage debridement and closure. His wounds were predominantly covered with split-thickness skin grafts. However, the dorsum of his left thumb revealed significant exposure of extensor tendon after debridement of devitalized tissue (Figure 3A). Therefore, a perforator-based propeller flap supplied by the princeps pollicis artery was designed over the proximal phalanx and was transposed to cover the exposed tendon (Figure 3B–F). A skin graft was used to close the donor site. At 3-month follow-up, the left thumb was well healed and the patient demonstrated normal range of motion at the interphalangeal joint (Figure 4). This case further establishes that propeller flaps used for acute burn wound coverage can provide adequate coverage and preserved range of motion.

Case 3

A 9-year-old woman was victim to a severe scald burn to her face, thorax, left arm, and left leg when she was 15 months of age. Her injuries were initially treated by excisional debridement and autografting. As she grew, postburn scarring and skin graft contraction began to tether her left elbow. She developed progressive tightness of her left antecubital area on full extension (Figure 5A). At the age of 9, she was taken to the operating room for scar contracture release. The wounds created by release of the scar could not be adequately closed with adjacent tissue rearrangements (Figure 5B–D). Therefore, a perforator-based propeller flap designed on the upper lateral arm was used to close the wounds, in addition to local tissue rearrangements in the form of Z-plasties, after release of this burn scar contracture. The flap was based distally on a perforator from the posterior radial collateral artery. The flap was rotated 120° to fill the defect (Figure 6A–F). The patient was discharged on postoperative day 2 and began physical

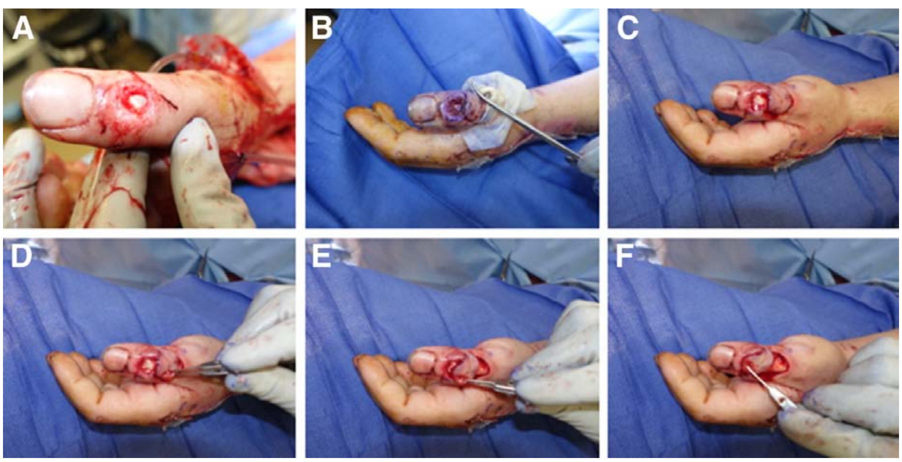

Figure 3. A. Exposed extensor tendon after debridement of devitalized tissue. B, C. A perforator-based propeller flap supplied by the princeps pollicis artery was designed over the proximal phalanx. D–F. The flap was transposed to cover the exposed tendon.

Figure 4. Left thumb was well healed and displayed normal range of motion at the interphalangeal joint at 3-month follow-up.

therapy on postoperative day 11. The patient demonstrated near full range of motion at 3 weeks after surgery. At 6 months, her incisions were well healed and she exhibited full range of motion without tightness at the elbow.

Case 4

A 47-year-old woman had been treated at our institution for severe thermal burns to the lower extremity 20 years earlier. She had since developed a chronic ulcer of the lateral aspect of the left leg as a result of burn scarring. Despite treatment with topical antimicrobials, the wound failed to heal because of the severe nature of the scar. She was therefore taken to the operating room for excisional debridement of the wound and coverage. To fill the defect after excision, a propeller flap based on the peroneal vascular system and consisting of previously skin-grafted skin and subcutaneous tissue was designed. The flap was rotated 180° to close the defect. The donor site defect could not be closed primarily so a split-thickness skin graft was harvested (Figure 7). There were no complications in the postoperative setting. At 8-year follow-up, the flap continued to provide stable coverage.

DISCUSSION

Reconstruction with cutaneous flaps has many advantages compared with skin grafting in selected patients with burn injuries. Flaps provide durable coverage of wounds and vital structures, permit increased motion across joints, and usually provide superior aesthetics. The major limitation in the use of cutaneous flaps in acute burn care is their finite supply. This is particularly true for patients with extensive burns.

In many cases, an excellent option for burn reconstruction is the use of adjacent skin flaps. Adjacent healthy skin provides the closest match possible to the injured site with respect to color, texture, and hair-bearing qualities.[8] Perforator-based propeller flaps enable vascularized wound coverage using local tissues; however, they are rarely described in the

Figure 5. A. Tethering of the elbow because of postburn scarring and skin graft contraction with tightness of left antecubital area on full extension. B–D. At the time of scar contracture release, the wounds created by release of the scar could not be adequately closed with adjacent tissue rearrangements.

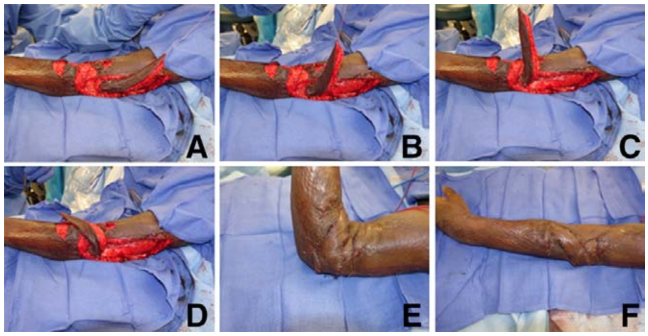

Figure 6. A. A perforator-based propeller flap designed on the upper lateral arm. The flap was based distally on a perforator from the posterior radial collateral artery. B–D. The flap was rotated 120° to fill the defect. E, F. The flap was used in conjunction with local tissue rearrangements (Z-plasties) for adequate closure.

context of burn care. In this article, we have detailed the use of propeller flaps in acute and reconstructive burn care.

Propeller flaps are a type of perforator flap in which cutaneous or subcutaneous tissue that has been "islandized" on one or two perforating (or septocutaneous) vessels is rotated or transposed into a defect. By skeletonizing a perforator vessel adjacent to the defect, an islandized flap can rotate about a pivot point up to 180°. The propeller flap has gained favor in reconstructive circles, proving itself a reliable source of vascularized tissue for soft tissue reconstruction. Propeller flaps can be designed for a variety of defects—whether big or small, or deficient in one tissue type or those that are composite in nature. In fact, it has been reported that a single perforator, in addition to supplying the tissues within its angiosome, is capable of supplying tissues that are more than two vascular territories away.[9] Unlike many axial flaps, propeller flaps are harvested in a way that avoids disruption of the source vessel.

Figure 7. A propeller flap based on the peroneal vascular system and consisting of skin and subcutaneous tissue was designed. The flap was rotated 180° to close the defect. The donor site defect could not be closed primarily, so a split-thickness skin graft was harvested.

The propeller flap has been described for the reconstruction of defects related to oncologic resection, trauma, pressure sores, and chronic wounds. Only a handful of limited reports exist, however, describing its use in burn care. In one study of seven patients, Aslan et al.[10] reported that propeller flaps were successfully used for the treatment of postburn elbow contractures. In addition to improving joint range of motion, the benefits of the propeller flap included an easy design, rapid elevation, and a single-stage repair. In a slightly larger study of 16 patients, Panse et al[11] used propeller flaps for the reconstruction of postburn sequelae in both upper and lower extremities. The results were promising as the flaps prevented return of joint contracture and improved patient functionality. Additional studies of perforator flaps (but not specifically propeller flaps) have also reported positive results with respect to postburn flexion deformities.[12–14]

In the current analysis, we describe the use of perforator-based propeller flaps in 21 cases for burns across the body. In the majority of cases, flaps were used for the reconstruction of postburn deformities, such as chronic wounds, scar contracture, and limited joint range of motion. Our results are in-line with the previous reports that perforator-based propeller flaps are efficacious for the reconstruction of these postburn sequelae. Indeed, in our study of 15 propeller flaps used in the reconstructive stage of burn care, all flaps provided stable coverage and/or improved range of motion at long-term follow-up.

In the current study, we have gone a step further than what has been previously described by using perforator-based propeller flaps for the treatment of acute burn wounds as well. Indeed, a variety of flaps have been used successfully in acute burn management including local and free flap options.[15] Propeller flaps, however, have not been reported in this context. Indications for flap use in this setting included coverage of exposed vital structures, wound closure, and preservation of range of motion. The majority of flaps (83%) were successful in the immediate postoperative period although one flap was lost because of venous insufficiency. This required an additional trip to the operating room for debridement and coverage with autograft. Of note, our study is limited by a small sample size and inadequate follow-up. Nevertheless, we describe important indications for the consideration of propeller flaps in acute burn care.

Another important aspect of the current study highlights the use of vascularized tissue from less than ideal donor sites. In 1990, Cherup et al[16] demonstrated that a flap elevated from an area that had been previously injured and subsequently grafted could still result in an excellent functional outcome. In the current analysis, nine propeller flaps were harvested from a region that had been burned and subsequently grafted or allowed to heal. Despite minor complications in three flaps in this group, all flaps harvested from previously injured donor tissue were ultimately successful in achieving stable wound coverage and preservation of range of motion. Therefore, even in the case of a large total body surface area burn, where there is little uninjured skin, vascularized tissue should be considered as an option for reconstruction. In addition, the fact that the three cases of partial flap loss seen in our study occurred only in flaps harvested from suboptimal donor tissue further supports the safety and efficacy of perforator-based propeller flaps that are harvested from uninjured tissue.

A further limitation of the current study is its retrospective design. Moving forward, it is important to systematically study the use of perforator-based propeller flaps in the care of burn patients on a larger scale. This may be done prospectively, or more realistically, by pooling data from various institutions. Several small studies, including ours, have demonstrated their utility in postburn reconstruction. It is also important to consider their use, as we have done here, in cases of acute burn deformity that would benefit from flap coverage.

Finally, it is important to note that perforator flap surgery requires significant expertise. Poor planning and execution can result in flap loss. We agree with other authors that the risk of complications can be reduced by following certain principles: identify perforating vessels preoperatively by hand-held Doppler; use a modest initial incision to localize the main perforator before wide dissection; preserve all encountered perforators until the best one is selected; and safely and completely dissect the pedicle before raising the flap island.[8,17]

CONCLUSION

Perforator-based propeller flaps provide reliable vascularized soft tissue for the coverage of vital structures, resurfacing of wounds, scar contracture release, and preservation of range of motion across joints after burn injury. Furthermore, our study supports their utility in both the acute and reconstructive phases of burn care. They are versatile, safe, relatively easy to harvest, and useful anywhere on the body where a perforator vessel is present.

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