Preservation of Hand Function Using Muscle Perforator Flaps

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Abstract Adequate soft tissue coverage is imperative after any interventions performed to maximize or preserve hand function. Although this can most simply be achieved by primary closure or a skin graft if possible, often a vascularized flap will be preferable, especially if a later secondary procedure is planned. Even moderately sized skin deficits of the upper extremity, and especially if involving the hand itself, can be better covered using a free tissue transfer. Many reasonable options in this regard are available. Muscle perforator flaps, as a relatively new variant of a fasciocutaneous flap, have unique attributes, including availability, diversity, accessibility, large size, and lengthy vascular pedicle, and since no muscle need be included, donor site function is preserved. As is shown here in a series of nine muscle perforator flaps in eight patients, these represent yet another alternative that should be considered if selection of a free flap is indicated to maintain hand function.

Keywords Muscle perforator flaps · Upper extremity · Free flaps

Introduction

No matter how elegant any musculoskeletal or other structural repair has been, appropriate soft tissue restoration is just as essential to maximize the ultimate recovery of hand function. This can be accomplished most simply with skin grafts or if vital structures, including neurovascular or musculotendinous units, bone or joints, and/or fixation devices or other foreign materials are exposed, then a vascularized flap would be preferable. Local upper extremity muscle or fasciocutaneous flaps usually are adequate only for extremely small defects [9]. Besides, preservation of function mitigates against the arbitrary selection of a questionably expendable upper extremity muscle unit as a flap. Although relevant in the past, distant pedicled flaps from the groin [14] or even trunk [16] today primarily serve a salvage role, as these transfers must be staged and their requisite period of immobilization cannot avoid causing dependency and joint stiffness. Some have proselytized regional flaps from the forearm, including the reverse radial or ulnar forearm flap or posterior interosseous flap as then the next best solution [10]. On many occasions, however, even though much more complex, a better option may instead be a free tissue transfer since these also permit single stage coverage, do not further violate the ipsilateral upper extremity, and will always be the most suitable alternative for the most severe or even moderate-sized wounds [7]. Selection of a free flap donor site appropriate for hand coverage requires that it be thin enough to permit flexibility that allows adequate joint movement, obtainable with the patient in a supine position so that multiple teams can work synchronously, availability of composite tissues if desirable, and all this while resulting in little donor site deformity. Previous algorithms have suggested muscle flaps, including latissimus dorsi, serratus anterior, and

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gracilis [7]; but these may have later unpredictable atrophy and all must be skin-grafted, causing a non-aesthetic final appearance. Fascia flaps such as the temporoparietal flap [6], albeit thin and providing a slick, gliding surface, similarly must be skin-grafted. These choices have been supplanted by other fasciocutaneous free flaps such as the radial forearm [10], lateral arm [17], and dorsalis pedis [1], although the donor site of the latter has always been problematic. Another emerging subset of fasciocutaneous flaps are muscle perforator flaps, whose role in upper extremity coverage has yet to be fully delineated.

According to Wei et al. [19], a “true” muscle perforator flap represents the cutaneous portion of what traditionally have been known as musculocutaneous flaps. Circulation to the skin paddle depends solely on retention of musculocutaneous perforators and not on the muscle that serves only as a passive carrier, hence “muscle

perforator” flaps. Thus, a true muscle perforator flap requires a somewhat tedious dissection of those musculocutaneous perforators through the muscle itself back to the common source or “mother” vessel. No muscle need be included, and function is preserved—a touted major advantage of muscle perforator flaps. Although a universal consensus does not exist, in an attempt to standardize the nomenclature, the Canadian system [4] has been most widely adopted where these flaps are named after their source vessel.

Wang et al. [18] and Koshima et al. [12] have previously reported using the lateral circumflex femoral artery perforator–vastus lateralis free flap (LCFAP–vl; better known as the “anterolateral thigh flap”) for upper extremity coverage. Xie et al. [22] have similarly used only the medial sural artery perforator (MSAP) free flap for the hand. Pedicled paraumbilical perforator-based flaps from the abdomen,

Figure 1 Schematic listing of the source vessel and muscle traversed (*subscript*) for most presently described muscle perforator flaps. The corresponding standardized nomenclature using the Canadian convention [4] is given as the *abbreviation in parentheses* of that source vessel with “A” for artery and “P” for perforator. Those territories shaded in light gray (and marked by an asterisk) are particularly suitable as free flaps for upper extremity coverage. ABD Abdominis,

AIAP anterior intercostal AP, INT internal, LAT lateralis, latissimus, LS lateral sural, MAX maximus, MS medial sural, PEC pectoralis, PIAP posterior intercostal AP, TFL tensor fascia lata; *italicized letters* after hyphen correspond to first letters of the muscle traversed, e.g., *Pma* pectoralis major or level *n* in Arabic numerals, e.g., 8 for eighth intercostal perforator).

technically ultimately based on the deep inferior epigastric artery so deep inferior epigastric artery perforator (DIEAP) flaps, have also been described [11, 23]. The role of these and other potential muscle perforator flaps (Fig. 1) deserves to be further investigated.

Methods and Materials

A retrospective review of those patients who had muscle perforator flaps for upper extremity coverage specifically to protect structures directly involved in hand function or to allow their secondary reconstruction revealed eight individuals over the period 2002–2007. There were a total of nine flaps transferred in these eight individuals. All were free flaps, harvested according to the guidelines as enumerated by Blondeel et al. [3]. Parameters specific to each flap were tabulated for comparison. These included

the number of perforators per flap, flap size, donor site treatment, and outcome (Table 1).

Results

Successful coverage was ultimately achieved in all patients with a muscle perforator flap, although 1 DIEAP flap failed secondary to venous congestion that could not be reversed in spite of emergency re-exploration for a success rate in this small series of 89%. Four different donor sites were selected, all accessible with the patient in a supine position to facilitate simultaneous access to the involved upper extremity. The LCFAP–vl, sic. anterolateral thigh flap, was most commonly used and always for defects requiring the largest surface area for coverage. Unfortunately, in each case, because of the large flap size required, a non-aesthetic skin graft was necessary for this donor site.

Table 1 Indications for upper extremity muscle perforator flaps.

Age/ sex	Etiology	Hand compromise	Initial Rx	Donor site (Rx)	Flap size (cm)	Perfs #	Recipient site	Other procedures	Complications
1.32M	Electrical burn	Forearm ulnar nerve gap	STSG	MCFAP–g (I ⁰)	6×16	2	Ulnar a, v SubQ v	Vascularized nerve graft Flexor tenolysis	None
2.28M	MVA avulsion	Extrinsic flexor tendon adhesions Ulnar nerve gap (arm)	VAC	LCFAP–vl (STSG)	15×30	3	Brachial a Basilic v	Staged nerve graft	None
3.78M	Farm accident	Exposed extrinsic flexor tendons	STSG	LCFAP–vl (STSG)	10×20	2	Radial a, v Cephalic v	None	None
4.26M	Meat grinder	Median nerve laceration wrist	I ⁰	LCFAP–vl (STSG)	10×15	2	Ulnar a, v SubQ v	Vascularized nerve cable grafts	None
5.28M	MVA avulsion	Exposed extrinsic flexor tendons	MSAP free flap	MSAP (STSG)	8×16	2	Ulnar a SubQ v	None	None
6.22F	MVA avulsion	Exposed carpal bones	Radial forearm flap	DIEAP (I ⁰)	18×20	2	Radial a SubQ v	Wrist arthrodesis	Total necrosis
			DIEAP free flap	LCFAP–vl (STSG)	18×20	3	Radial a Brachial v		None
7.19M	MVA avulsion	Exposed extensor tendon repairs dorsum hand	Finger fillet	MSAP (I ⁰)	5.5×12	1	Radial a SubQ v	None	None
8.20F	MVA avulsion	Loss finger extension	STSG	LCFAP–vl (STSG)	14×28	2	Brachial a, v Basilic v	Staged FCR transplant	None

Rx Treatment, *Perfs* perforators, *M* male, *F* female, *STSG* split thickness skin graft, *I⁰* primary closure, *a* artery, *v* vein, *subQ* subcutaneous, *MVA* motor vehicle accident, *VAC* vacuum-assisted closure, *FCR* flexor carpi radialis, *DIEAP* deep inferior epigastric artery perforator, *LCFAP–vl* lateral circumflex femoral artery perforator–vastus lateralis, *MCFAP–g* medial circumflex femoral artery perforator–gracilis, *MSAP* medial sural artery perforator

Two or more musculocutaneous perforators were retained with all but 1 flap. Because of the large size of most of these flaps, a distal perforator was always intentionally sought to theoretically insure distal perfusion as well as to serve as a back-up in the case of inadvertent injury to the major perforator that in all cases was actually preserved. In addition, unrecognized pedicle twisting, as can occur with retention of only a solitary perforator, would be impossible.

As is not too unusual today in a referral practice, a technically simpler alternative was the initial treatment used in all but one patient. This is in spite of the fact that a later-staged reconstruction was planned in two patients (Fig. 2), and three others had interventions concomitant with a free flap that then became essential for overall coverage.

The forearm arteries, always used in end-to-side fashion, were most commonly the arterial recipient site. However,

since the forearm venae comitantes typically are diminutive, subcutaneous veins in all but one case were adequate for outflow. In that exceptional case, a LCFAP–vl flap was especially valuable for its long pedicle to allow to reach outside the venous system of the forearm, which had failed (case #6) to a brachial vein near the antecubital fossa. Fortunately, there were no other complications.

Discussion

Nakajima et al. [15], in their now classic treatise that identified all the potential deep fascia perforators that could nourish fasciocutaneous flaps, suggested that the larger musculocutaneous perforators (i.e., today defined as having a caliber exceeding 0.5 mm or with visible pulsations) that they called “perforating cutaneous branch of muscular

Figure 2 Case #8. **a** Extensive left dorsal forearm skin and extensor muscle avulsion; **b** initial presentation after wound had been skin-grafted elsewhere; note the inability to fully extend the ulnar three fingers with the wrist extended; **c** boundaries of LCFAP–vl flap on the antero-lateral left thigh centered about perforator “x” found using audible Doppler, near mid-point of line drawn from anterior superior iliac spine to superior lateral border of patella; **d** suprafascial dissection of the flap identified another large perforator exiting via the vastus lateralis muscle (microgrid under musculocutaneous perforators); **e** the two perforators dangling from the LCFAP–vl free flap, with their common descending branch of the lateral circumflex femoral vessels in microclamps; **f** at a second stage, a flexor carpi ulnaris (FCR) tendon transfer (above hemostat) was brought under the LCFAP–vl flap and interwoven with the common extensors of the ulnar three digits, just proximal to the extensor retinaculum of the wrist; **g** aesthetic improvement of the upper extremity with this LCFAP–vl flap, and fingers fully flexed during wrist extension; **h** and then fully extended by the FCR transfer.

vessels” would someday permit a new variant of a fasciocutaneous flap. Their prediction today is known as the muscle perforator flap, based on just those ideal musculocutaneous perforators.

The sine qua non of muscle perforator flaps is function preservation since muscle by definition is excluded. Other advantages include accessibility, improved aesthetics, diversity, immense size, and a potentially long vascular pedicle of caliber chosen to match the given recipient site. A major liability, especially for upper extremity problems, is excessive bulk that is commonplace in North Americans, even if the flap were to be thinned so that more traditional thin flap alternatives would be superior. In addition, anatomical anomalies and inconsistencies are in fact the norm to be expected.

Unpredictable venous congestion is another disadvantage as venous outflow does not necessarily parallel the perforator artery, as evidenced as the reason for the only failure in this series.

At least if based on the number of pertinent prior publications [13], the “Big 4” of muscle perforator flaps are the LCFAP–vl, DIEAP, superior gluteal artery perforator, and thoracodorsal artery perforator flaps. The latter two cannot be harvested with the patient supine, making their utilization for upper extremity problems difficult. The DIEAP flap is usually far too bulky, an attribute that is actually an advantage for autogenous tissue breast reconstruction [2]. Therefore, the LCFAP–vl flap remains as the workhorse flap that some even consider the “ideal” soft tissue flap for all seasons [20] (Fig. 2).

Nevertheless, as shown in this series, other muscle perforator flap donor site possibilities not resorting to free-style free flaps [21] do exist. A major disadvantage of the LCFAP–vl flap can be the conspicuous skin graft necessary to close a large donor site. The one DIEAP flap selected was so chosen to allow a concomitant cosmetic abdominoplasty, although the flap itself was too bulky. A better choice, if thin enough, is the medial circumflex femoral artery perforator–gracilis flap (also known as the medial groin flap), as the donor defect even if not possible to be closed primarily can always be easily hidden by clothing [8]. Even in the obese individual where a LCFAP–vl flap may be awkward, the lower leg may still be thin enough to consider a muscle perforator flap. The peroneal artery perforator–soleus flap is usually used in concert with a fibula vascularized bone graft. The MSAP flap can be easily reached with the knee flexed and is usually thin enough even for hand coverage [15] (Fig. 3), although the donor site scar can be obvious.

Any schema suggesting alternatives for skin coverage in all regions of the upper extremity will include the option for free flaps for large defects and typically even for moderate-sized defects of the hand itself [5, 7]. Many donor sites exist that can preferably replace these skin deficits with aesthetically superior cutaneous flaps. Although muscle perforator flaps intrinsic to the upper extremity are theoretically possible, even as a free flap from another body region, these sometimes represent a reasonable option that should not be overlooked during this selection process.

Figure 3 Case #7. **A** mangled left hand with exposed extensor tendons to the long and ring fingers, eventually not coverable by fillet flaps of the remaining index and little fingers; **b** with left knee flexed, boundaries of a MSAP flap marked on medial left calf about

perforator “x” heard with an audible Doppler; **c** relatively thin MSAP free flap with solitary perforator from medial sural vessels (dangling in microclamp); **d** dorsal view of healed hand; **e** side view demonstrating unimpeded pinch.

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