Rotational Flaps in Complicated Partial Foot Amputation: A Retrospective Review to Assess Initial Healing and Flap Survival

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STATEMENT OF PURPOSE

Patients undergoing partial foot amputation commonly have soft tissue deficits associated with neuropathic wounds, gangrene, and recent open amputation. Level of amputation is substantially influenced by the extent and location of tissue deficits as surgeons prefer to achieve primary closure with native tissue. Rotational flaps can be incorporated into partial foot amputation to achieve soft tissue coverage thereby avoiding a more proximal amputation. We have previously described specific flap designs for use in common amputation procedures on the forefoot; however, there remains uncertainty regarding healing potential and flap durability in patients with the multiple comorbid conditions typically seen with complicated neuropathic and ischemic wounds. Observations at our institution suggested that a large percentage of flaps heal uneventfully when performed in patients with complex partial foot amputations despite multiple comorbid conditions. This research retrospectively evaluated initial flap healing success and limb survival in consecutive patients undergoing specified flaps incorporated into partial forefoot amputation procedures. We hypothesized that a large percentage of rotational flaps healed successfully and remained healed at intermediate-term follow-up despite comorbid conditions.

LITERATURE REVIEW

Several published articles describe nontraditional flap closure techniques as adjunctive procedures in complicated partial foot amputations. Mahan recommended full-thickness flaps on the weight-bearing surface of the foot as a successful approach for plantar defects that cannot be repaired by primary closure (1). Their durability is such that can withstand weight-bearing stress once healed (2). Multiple case series demonstrated positive results with respect to wound coverage and successful healing; however, large patient populations have not been studied and long-term follow-up data are lacking.

Boffeli and Peterson described rotational flap closure in partial 1st and 5th ray amputations in 2013. Case examples were presented to demonstrate flap design that utilizes viable tissue that is otherwise discarded with traditional amputation techniques (3).

Park et al., in 1997, described the successful incorporation of a lateral plantar artery angiosome (LPAA) flap for coverage of a large plantar medial wound without amputation (2). Boffeli and Waverly in 2016 described incorporation of medial and/or lateral plantar artery angiosome flaps into transmetatarsal amputation (TMA) (4).

METHODOLOGY

A level 3 retrospective study was performed using data from a five-year period (2011-2015). All procedures were performed at Regions Hospital in St. Paul, Minnesota by a single surgeon (TJB). Consecutive cases were identified through Current Procedural Terminology (CPT) codes for Adjacent Tissue Transfer or Rearrangement (14041 and 14301). Cases with flaps performed as adjunctive procedures in 1st ray, 5th ray, and transmetatarsal amputation were included. Cases involving digital flaps, flaps utilized for trauma, or flaps for conditions unrelated to partial forefoot amputation were excluded. Each case was reviewed for the presence of comorbid conditions at the time of surgery. Comorbidities assessed included: diabetes, peripheral neuropathy, osteomyelitis, peripheral vascular disease (PVD), gangrene, heterotopic ossification (HO), overweight/obesity, and Charcot neuroarthropathy. Other data collected included: age at the time of surgery, gender, laterality, level of amputation / flap design, and body mass index (BMI). Initial flap healing was assessed based on time to complete flap healing. Charts were reviewed from the time of surgery through the most recent follow-up visit. Flap survival outcome measures included incidence of wound recurrence, incidence of local revision, and incidence of subsequent more proximal amputation. Statistical analyses were performed using Spearman's Rho Correlation and a one-way ANOVA.

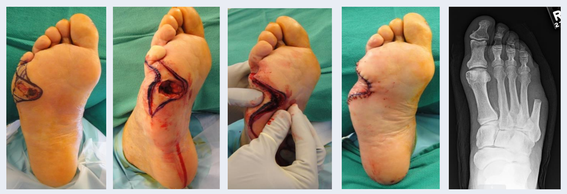
PROCEDURES

Rotational flaps are incorporated into partial foot amputation procedures in an effort to avoid open or more proximal amputation when closure of the soft tissue deficit is not possible with standard amputation incision placement. Amputation is ideally performed before the development of acute infection involving abscess, gas gangrene, or necrotizing fasciitis which allows single-stage flap closure. For acute infection, two-staged surgery allows successful incorporation of flap closure once infection is controlled. Partial foot amputation is particularly conducive to flap closure because broad bone resection creates laxity in the tissues that improves flap mobility. Flap designs, as described here, also utilize tissue that would otherwise be discarded with traditional amputation techniques and allow revision alternatives in cases with poor healing or recurrent infection (5). Flaps are incised full-thickness to bone and are raised at the sub-periosteal level when performing amputation. This allows optimal preservation of vascularity in angiosome-based flaps that include intrinsic muscles wherever possible. The level of bone resection should be short enough to avoid excessive pressure on the flap though flap durability should be adequate for wound coverage on the weight-bearing surface of the foot. Flaps are raised with minimal touch techniques and surgery is generally performed without a tourniquet. Drains are rarely used due intraoperative hemostasis and lack of dead space after flap closure. Incision and dissection is performed sharply with selective use of cautery to minimize tissue trauma. Larger vessels are tied and bleeding largely subsides by the time of closure. Stage 2 incision and drainage with washout of hematoma and bone margin biopsy during initial admission is not considered failure. Amputation technique and various flap designs are detailed in **Figure 1** for partial 1st ray amputation, **Figure 2** for partial 5th ray amputation, and **Figure 3-5** for TMA.

Figure 1. Rotational Flap Closure in Partial 1st Ray Amputation

Flap design for partial 1st ray amputation creates a flap from the medial side of the 1st proximal phalanx and metatarsal head which is used to cover wound deficits at the plantar 1st MPJ. The proximal arm curves superior and medially away from the weight-bearing surface to extend along the medial midline of the 1st metatarsal. This technique minimizes postoperative weight-bearing on the incision and is more easily converted to TMA should that become necessary. Note that level of metatarsal resection allows weight-bearing on native plantar tissue rather than on the rotated flap to minimize wound recurrence (3).

Figure 2. Rotational Flap Closure in Partial 5th Ray Amputation



Flap design for partial 5th ray amputation mirrors that of the 1st ray. This procedure is indicated for plantar 5th MPJ wounds complicated by osteomyelitis. The flap incision design preserves healthy tissue from the dorsal lateral aspect of the 5th proximal phalanx and metatarsal head that would otherwise be discarded with traditional 5th ray amputation (3).

Figure 3. TMA with Lateral Plantar Artery Angiosome (LPAA) Flap Closure

Plantar artery angiosome-based flaps are based on angiosomes described by Attinger in 2006 (6) and are combined with TMA to accomplish coverage of broad medial, lateral, or central wounds of the forefoot. Plantar medial soft tissue defects were treated with LPAA flaps as shown here (4). Note plantar pivot point and medial rotation of the flap.

Figure 4. TMA with Medial Plantar Artery Angiosome (MPAA) Flap Closure

Plantar lateral soft tissue defects were treated with MPAA flaps in conjunction with TMA (4). Note short metatarsal resection to allow improved mobility of the flap when needed.

Figure 5. TMA with Combined MPAA and LPAA Flap Closure

Central plantar wound defects were treated with combined LPAA and MPAA flaps in conjunction with TMA (4) which we refer to as the V to T TMA flap.

Table 1. Flap Design Frequency and Initial Healing Rates

Amputation Type	Frequency	Healed	
1st Ray Amputation Flap	20	15	75.0%
5th Ray Amputation Flap	26	23	88.5%
TMA Case Total	37	31	83.8%
LPAA Flap	16	14	87.5%
MPAA Flap	13	10	76.9%
MPAA+LPAA Flaps	8	7	87.5%

Table 2. Prevalence of Comorbid Conditions

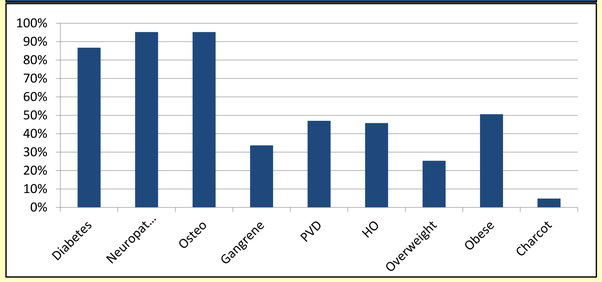
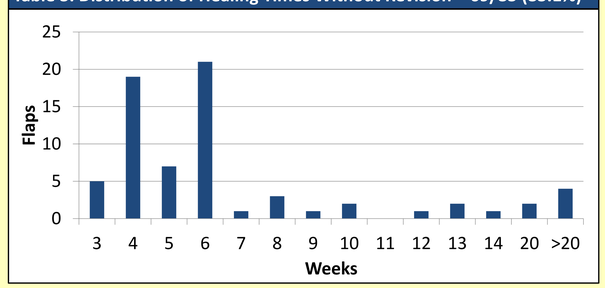


Table 3. Distribution of Healing Times Without Revision – 69/83 (83.1%)



RESULTS

135 flaps were performed during the study period. 83 flaps in 71 patients and 77 feet met the inclusion criteria. 52 flap cases were excluded due to trauma etiology or were unrelated to the amputation procedures described. There were 55 males and 16 females. The average patient age at the time of surgery was 62.5 ± 12.2 years (range 38-94 years). The average length of follow-up was 19.4 months and ranged from 4 weeks to 6 years. Distribution based on level of amputation / flap design and initial healing success is shown in **Table 1. Table 2** shows prevalence of comorbid conditions.

73/83 (88.0%) flap procedures achieved complete wound coverage at the time of initial flap surgery while the remaining 10/83 (12.0%) were left with a residual wound deficit that required secondary healing. 54/83 (65.1%) flaps healed uneventfully within the initial 6 weeks post-operatively and 69/83 (83.1%) ultimately healed without further operative intervention. The distribution of healing times following initial flap closure without revision is shown in **Table 3**. Average healing times for each level of amputation / flap design are compared in **Table 4**. An additional 6/83 (7.2%) flaps healed following local revision surgery for an overall successful healing rate of 75/83 (90.4%). 8/83 (9.6%) flaps did not heal successfully such that 6 required more proximal amputation (2 TMA, 4 BKA) and 2 passed away from unrelated conditions during the initial healing timeframe.

Intermediate term monitoring identified 21/75 (28.0%) with re-ulceration at the surgical site which was treated with local surgical revision in 11/21 (52.4%) cases. 7/11 (63.6%) of local revision for re-ulceration involved resection of heterotopic ossification, though the association between surgical revision and the presence of heterotopic ossification was not found to be statistically significant based on an r value of 0.1884 and a p value of 0.08807. Another 4/21 (19.0%) that suffered from re-ulceration were treated with more proximal partial foot amputation (2 TMA, 1 BKA, 1 AKA). The remaining 6/21 (28.6%) were treated successfully with local wound care. Data regarding re-ulceration rates are shown in **Table 5.**

Flap survival was analyzed in a subgroup of 62 flaps with a length of follow-up greater than 6 months. 41/62 (66.1%) flaps survived at an average follow-up in this subset of 28.3 months (range 27-317 months) and 21/62 (33.9%) required more proximal amputation. Of those with subsequent amputation proximal to the flap, 11/21 (52.3%) required TMA, 8/21 (38.1%) required BKA, and 2/21 (9.5%) required AKA.

Table 4. Distribution of Amputation Flap Healing Times

Flap Design / Level of Amputation	Average Healing Time (weeks)
1st Ray Amputation Flap	6.17
5th Ray Amputation Flap	7.28
TMA with Lateral Plantar Artery Angiosome Flap	9.61
TMA with Medial Plantar Artery Angiosome Flap	10.25
TMA with Combined MPAA and LPAA Flaps	5.21
Total	7.73*

*A statistically significant difference in average healing times was not seen between amputation groups based on p value of 0.465 and f ratio of 0.908

Table 5. Incidence of Re-ulceration at Healed Flap Surgical Site

Re-ulcerations Related to Surgical Site	21/75 (28.0%)
Healed with Local Surgical Site Revision	11/21 (52.4%)
Treated with Proximal Partial Foot Amputation	4/21 (19.0%)
Healed with Local Wound Care	6/21 (28.6%)

ANALYSIS & DISCUSSION

This retrospective study was conducted to assess initial healing and intermediate-term outcomes of specific flap designs used as an adjunct to common amputation procedures. Full-thickness rotational flaps are likely underutilized in limb salvage surgery due to low expectations of healing and flap survival in this challenging population. Flaps allow complete coverage of osseous structures and soft tissue defects which limits the potential for residual ulceration or infection, especially when treating osteomyelitis (3). The tactful preservation of vascularized flaps also improves the delivery of antibiotic therapy to the area of need and allows coverage with native tissue as opposed to scar tissue associated with secondary healing or skin grafts.

A high percentage of rotational flaps healed successfully despite comorbid conditions with an overall initial healing rate of 75/83 (90.4%). Only 6 of the patients in this group required local revision surgery during the healing phase. Peripheral neuropathy and osteomyelitis were the most prevalent comorbid conditions, both occurring in 79/83 cases (95.2%). 25/28 (89.3%) flaps used to treat gangrene and 66/79 (83.5%) flaps used to treat osteomyelitis healed successfully without revision. The data support the use of full-thickness flaps in the treatment of chronic wounds and amputation in diabetic populations, including those with severe limb-threatening infection and critical limb ischemia.

All patients in this study were treated with local rotational flaps that were used to cover plantar weight-bearing wounds. The 28.0% re-ulceration rate is not surprising considering the high incidence of neuropathy. Most were treated with minor intervention while 4/21 flaps that re-ulcerated required proximal amputation (2 TMA, 1 BKA, 1 AKA). 41/62 (66.1%) flaps with longer than 6 month follow-up survived at an average follow-up of 28.3 months which we feel is a measure of success based on the high percentage that would have otherwise been treated with open amputation, TMA, or leg amputation as a primary procedure if flap surgery was not initially performed. The 10/83 (12.0%) cases that experienced limb loss could all be attributed to chronic osteomyelitis, peripheral arterial disease, or gangrene (gas, wet, dry).

The results of the study are limited by the retrospective nature of the review. Length of follow-up was a challenge because our institution is a Level 1 trauma center that draws complicated cases from distant areas and patients often seek follow-up care near home. All cases were performed by a single surgeon which improves standardization of surgical procedure and reproducibility of findings. Cases were also consecutive which decreases exclusion bias. The large sample size increases the power of the study and allows us to draw conclusions that can be applied to a broader population. The present study concludes that the use of full-thickness rotational flaps in conjunction with partial pedal amputation is an effective limb salvage technique that can avoid or delay proximal amputation despite comorbid conditions.

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