Radial Forearm Free Flap Donor Site Morbidity

Ulnar-Based Transposition Flap vs Split-Thickness Skin Graft

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Objectives: To evaluate morbidity associated with the radial forearm free flap donor site and to compare functional and aesthetic outcomes of ulnar-based transposition flap (UBTF) vs split-thickness skin graft (STSG) closure of the donor site.

Design: Case-control study.

Setting: Tertiary care institution.

Patients: The inclusion criteria were flap size not exceeding 30 cm², patient availability for a single follow-up visit, and performance of surgery at least 6 months previously. Forty-four patients were included in the study and were reviewed. Twenty-two patients had UBTF closure, and 22 had STSG closure.

Main Outcome Measures: Variables analyzed included wrist mobility, Michigan Hand Outcomes Questionnaire scores, pinch and grip strength (using a dynamometer), and hand sensitivity (using monofilament testing over the radial nerve distribution). In analyses of operated arms vs nonoperated arms, variables obtained only for the operated arms included Vancouver Scar Scale scores and visual analog scale scores for Aesthetics and Overall Arm Function.

Results: The mean (SD) wrist extension was significantly better in the UBTF group (56.0° [10.4°] for nonoperated arms and 62.0° [9.7°] for operated arms) than in the STSG group (59.0° [7.4°] for nonoperated arms and 58.4° [12.1°] for operated arms) (P = .02). The improvement in wrist range of motion for the UBTF group approached statistical significance (P = .07). All other variables (Michigan Hand Outcomes Questionnaire scores, pinch and grip strength, hand sensitivity, and visual analog scale scores) were significantly better for nonoperated arms vs operated arms, but no significant differences were observed between the UBTF and STSG groups.

Conclusions: The radial forearm free flap donor site carries significant morbidity. Donor site UBTF closure was associated with improved wrist extension and represents an alternative method of closure for small donor site defects.


Three decades after the first description by Yang et al,1 the radial forearm free flap (RFFF) has become a workhorse in head and neck reconstruction. Its thinness, pliability, pedicle length, and vessel size are particularly suited for oropharyngeal and oral cavity reconstruction.2

Although popular, the RFFF is associated with significant donor site morbidity. Common early complications include wound breakdown and skin graft loss, resulting in delayed wound healing and tendon exposure.3,4,5 Previous studies of long-term consequences have demonstrated reduced wrist mobility,4,5 wrist or hand weakness,4,5 sensory deficits,5,6,7 persistent pain,5,8 decreased hand dexterity,6,9 and cosmetic deformity3,5,6,7 in objective and subjective assessments.

A split-thickness skin graft (STSG) is most frequently used to close the donor site defect.3,3 The STSG has been used with artificial dermis with some success.11,12 Alternative methods of closure include full-thickness skin graft from the forearm,13 inner arm,14 and abdomen,15 as well as the use of tissue expanders,16 local flaps,17,19 or free flaps.20 Few studies12,13,22 have compared the different methods, and they failed to identify a technique of choice.

In 1988, Elliot et al17 described their use of the ulnar-based transposition flap (UBTF) based on distal perforators from the ulnar artery as a reliable technique for the closure of small to medium donor site defects. This method allows for primary-intention wound healing and improved coverage of the tendons, nerves, and muscles, which should theoretically decrease donor site morbidity.
This study compares UBTF closure vs STSG closure of the RFFF donor site. Long-term function and aesthetics are evaluated.

METHODS

PATIENT SELECTION

A case-control study design was used. Patients were identified from an institutional database of head and neck reconstructions since January 1, 2003, which included more than 400 patients. The study protocol was approved by the ethics committee of the University of Toronto, Toronto, Ontario, Canada, and informed consent was obtained from all participants. The inclusion criteria were RFFF reconstruction, flap size not exceeding 30 cm² (eg, 6 × 5 cm), and performance of surgery at least 6 months previously. A defect size of 30 cm² or less theoretically enables the use of either technique of forearm closure. The exclusion criteria were any preexisting condition affecting both upper extremities that interfered with the study analysis (eg, patients with wrist arthritis or diabetic neuropathy).

Because UBTF closure was performed far less frequently during past years, this cohort was identified first. Thirty-six patients with UBTF reconstruction who met the inclusion criteria were identified in the database and were invited by mail or telephone call to participate in the study. Twenty-two patients who were available for a follow-up examination were included in the study (UBTF group).

Patients who underwent STSG closure and met the same inclusion criteria were consecutively identified and invited to participate in the study. If a potential candidate refused to participate or did not respond to the invitation, a new patient was invited until 22 patients were available (STSG group).

A retrospective medical record review was performed to obtain additional patient data. These data included preexisting disease affecting hand function and postoperative donor site complications. During patient selection, 4 patients with STSG closure were excluded from the study. One patient had diabetic neuropathy, and 3 patients had severe hand or wrist arthritis.

SURGICAL TECHNIQUE

All RFFFs were harvested in a standard fashion by 2 of us (D.J.E. and K.M.H.) using a suprafascial dissection technique in both groups. Radial nerve sensory branches were identified and preserved. The STSGs were harvested from the thigh using a Padgett dermatome at a thickness of 0.35 to 0.45 mm. The UBTFs were performed based on the initial description by Elliot et al. The harvested RFFF skin paddles were designed with their long axis transversely across the wrist and with their width (short axis) not exceeding 5 cm (Figure 1). Defects not exceeding 8 cm in length were elevated. A V-to-Y plasty was performed at the proximal aspect of the incision. The STSG group underwent postoperative splinting for 7 days.

OUTCOME MEASURES

Objective measurements of donor site morbidity included pinch and grip strength, wrist mobility (extension, flexion, and range of motion), and hand sensitivity (using monofilament testing over the radial nerve distribution). These variables were obtained for the operated arms and for the nonoperated arms.

Pinch and grip strength was evaluated using a hydraulic hand dynamometer and pinch gauge (Jamar; J A Preston Corporation). Cutaneous sensation over the radial nerve distribution was measured using the Semmes-Weinstein monofilament technique (Touch-Test; North Coast Medical, Inc). Measured sensitivity thresholds represent the smallest size of monofilament that elicited a response.

Subjective measurements included the Michigan Hand Outcomes Questionnaire (MHQ), Vancouver Scar Scale (VSS), and visual analog scale (VAS) scores for Aesthetics and for Overall Function. The MHQ is a validated questionnaire that evaluates both hands relative to activities of daily living, work performance, pain, aesthetics, and overall patient satisfaction. Patients independently evaluated results using a 10-cm VAS for Aesthetics and for Overall Function marked with 3 descriptive terms (a score of 0 indicated very poor; 5, average; and 10, very good). The VSS, VAS for Aesthetics, and VAS for Overall Function scores were obtained only for the operated arms. The aesthetic outcome was also assessed using the VSS. The VSS includes 4 measures of pliability, height, vascularity, and pigmentation. The VSS scores were rated by one of us (C.T.) who is familiar with this instrument.

STATISTICAL ANALYSIS

The primary statistical analysis was 2-way repeated-measures analysis of variance that included a between-group factor (STSG vs UBTF) and a within-group factor (operated arm vs nonoperated arm) on each set of functional variables. For variables that did not involve both arms, the 2-tailed t test was used to assess treatment differences. The level of significance was set at α = .05 for all tests. Commercially available statistical software (SAS 9.1.3; SAS Institute, Inc) was used.

Table 1. Patient Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>STSG Group (n = 22)</th>
<th>UBTF Group (n = 22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (range), y</td>
<td>65 (20-86)</td>
<td>66 (32-88)</td>
</tr>
<tr>
<td>Sex, No.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>Female</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Flap size, mean (SD), cm²</td>
<td>22.9 (4.9)</td>
<td>19.8 (3.6)</td>
</tr>
<tr>
<td>Donor site on dominant arm, No. (%)</td>
<td>1 (5)</td>
<td>0</td>
</tr>
<tr>
<td>Follow-up period, mean (range), mo</td>
<td>36 (6-83)</td>
<td>27 (7-82)</td>
</tr>
</tbody>
</table>

Abbreviations: STSG, split-thickness skin graft; UBTF, ulnar-based transposition flap.
RESULTS

PATIENT CHARACTERISTICS

Forty-four patients were included and reviewed at a single follow-up visit. Twenty-two patients with UBTF closure were matched to 22 patients with STSG closure. Demographic data are summarized in Table 1. The mean flap sizes were 19.8 cm² in the UBTF group and 22.9 cm² in the STSG group (P = .01). Two patients developed marginal skin necrosis of their UBTF, which required regular wound care and healed by secondary intention. Neither of these patients had exposed tendons, and no skin graft or reintervention was necessary. All skin grafts in the STSG group healed without local complication or partial skin graft loss.

OBJECTIVE MEASUREMENTS

Quantitative measures are listed in Table 2. The mean wrist extension was significantly better in the UBTF group (56.0° for nonoperated arms and 62.0° for operated arms) than in the STSG group (59.0° for nonoperated arms and 58.4° for operated arms). The mean wrist extension was better in the UBTF group for the operated arms, but this difference was not statistical significant. The improvement in wrist range of motion for the UBTF group approached statistical significance (P = .07). No between-group differences were found for other measured variables (pinch strength, grip strength, and hand sensitivity). A measurable difference between the operated arms and the nonoperated arms was noted for pinch strength, grip strength, and hand sensitivity. Pinch and grip strength measurements showed high variability (ie, high SDs) among patients. Overall, the mean values for wrist range of motion, pinch and grip strength, and hand sensitivity of the operated arms and the nonoperated arms in both groups remained within the range of published normative data for healthy subjects.25-28

SUBJECTIVE MEASUREMENTS

The mean MHQ scores were significantly lower for the operated arms than for the nonoperated arms (80.4 vs 90.5) (Table 3). For comparison, patients with rheumatoid arthritis had scores of 45 to 50 on the MHQ, and patients with carpal tunnel syndrome had scores of 50 (before surgery) to 63 (after surgery) on the MHQ. The MHQ scores were similar between the both groups. The VAS for Aesthetics and the VAS for Overall Function demonstrated slightly better improvement in the UBTF group, although the difference was not statistically significant. Similarly, the VSS showed greater improvement for the UBTF group, but again this difference was not statistically significant. More hypertrophied scars (ie, ropes, contractures, or height >2 mm) were observed in the UBTF group (3 patients) than in the STSG group (1 patient). In the UBTF group, 2 of 3 hypertrophied scars were observed in patients with darker skin types (Figure 2).

COMMENT

This case-control study compares STSG closure with UBTF closure in patients with forearm defects not exceeding 30 cm² after RFFF harvest. Although statistically significant, the difference in defect size between the 2 groups was small (3.1 cm²); therefore, our results warrant further study.

Low rates of early complications were found for skin graft loss and for UBTF partial necrosis. Skin graft-associated complication rates range from 0% to 30% in the literature. Previous studies on various ulnar artery–based local flaps reported low complication rates. Objective assessments showed similar results overall between STSG and UBTF. Only wrist extension and wrist range of motion were better in the UBTF group. All functional variables (wrist range of motion, pinch and grip strength, and hand sensitivity) were significantly reduced for the operated arms but remained within normative data for healthy subjects.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>Operated Arm</th>
<th>Nonoperated Arm</th>
<th>STSG Group vs UBTF Group</th>
<th>Nonoperated Arm vs Operated Arm</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrist range of motion</td>
<td>STSG</td>
<td>121.6 (25.8)</td>
<td>124.7 (17.7)</td>
<td>.07</td>
<td>.82</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UBTF</td>
<td>120.3 (18.8)</td>
<td>116.3 (21.0)</td>
<td>.02</td>
<td>.06</td>
<td></td>
</tr>
<tr>
<td>Extension</td>
<td>STSG</td>
<td>58.4 (12.1)</td>
<td>59.0 (7.1)</td>
<td>.69</td>
<td>.002</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UBTF</td>
<td>62.0 (9.7)</td>
<td>56.0 (10.4)</td>
<td>.02</td>
<td>.06</td>
<td></td>
</tr>
<tr>
<td>Pinch and grip strength, kg</td>
<td>Pinch</td>
<td>6.8 (2.9)</td>
<td>7.4 (3.1)</td>
<td>.98</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UBTF</td>
<td>7.3 (2.5)</td>
<td>7.8 (2.5)</td>
<td>.62</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grip</td>
<td>28.2 (16.0)</td>
<td>30.2 (14.9)</td>
<td>.62</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UBTF</td>
<td>31.4 (13.3)</td>
<td>33.9 (13.6)</td>
<td>.98</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Hand sensitivity threshold</td>
<td>STSG</td>
<td>2.6 (0.8)</td>
<td>2.3 (0.7)</td>
<td>.98</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UBTF</td>
<td>2.7 (0.8)</td>
<td>2.4 (0.6)</td>
<td>.98</td>
<td>&lt;.001</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: STSG, split-thickness skin graft; UBTF, ulnar-based transposition flap.
mal ranges of a standard population. Bardsley et al³ published a series on RFFF donor site morbidity and found no significant loss of hand power and wrist range of motion, except among those who sustained a radial fracture following composite flap harvest. However, other investigators have identified functional impairment of various degree among different variables that were measured. Timmons et al⁴ described high prevalences of reduced hand and wrist strength (40%), increased persisting wrist stiffness (27%), and decreased sensation over the radial nerve distribution. Richardson et al⁵ found significantly reduced wrist extension and pinch and grip strength compared with preoperative values in a subgroup of patients with fasciocutaneous flaps. In a case-control prospective series of 11 patients, Brown et al⁶ found measurable reduction in wrist flexion and pinch

**Table 3. Subjective Outcome Measures**

<table>
<thead>
<tr>
<th>Score</th>
<th>Group</th>
<th>Operated Arm</th>
<th>Nonoperated Arm</th>
<th>STSG Group vs UBTF Group</th>
<th>Nonoperated Arm vs Operated Arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Michigan Hand Outcomes Questionnaire⁷</td>
<td>STSG</td>
<td>82.6 (16.8)</td>
<td>91.5 (11.3)</td>
<td>⁴⁹</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>UBTF</td>
<td>78.1 (21.0)</td>
<td>89.6 (11.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual analog scale⁸</td>
<td>Overall function</td>
<td>STSG</td>
<td>6.9 (2.6)</td>
<td>NA</td>
<td>⁶３</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UBTF</td>
<td>7.3 (2.7)</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aesthetics</td>
<td>STSG</td>
<td>6.4 (2.2)</td>
<td>NA</td>
<td>⁵⁹</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UBTF</td>
<td>6.8 (2.5)</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Vancouver Scar Scale⁹</td>
<td>STSG</td>
<td>4.0 (2.2)</td>
<td>NA</td>
<td>⁶⁰</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>UBTF</td>
<td>4.4 (2.9)</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: NA, not applicable; STSG, split-thickness skin graft; UBTF, ulnar-based transposition flap.

⁷ Score range, 0 to 100.

⁸ Score range, 0 to 10.

⁹ Score range, 0 to 14.

**Figure 2.** Long-term postoperative results of ulnar-based transposition flap closure (A-C) and split-thickness skin graft closure (D-F). A and B, Good results. C, Hypertrophic scar. D, Good results. E, Widening of the proximal scar and irregular skin graft surface. F, Divot deformity of the skin graft area and thick indurated proximal scar.
strength associated with RFFF harvest. Notably, Toschka et al. found more pronounced postoperative limitation of wrist movements in patients who underwent RFFF harvest on their nondominant limb. More recently, Sardesai et al. found no significant functional decrease in quantitative measurements (mobility and strength) following RFFF tissue transfer, whereas de Witt et al. reported only diminished pinch strength. There is also conflicting evidence as to the level of sensory loss experienced over the radial nerve distribution. Using monofilament testing, we found significantly higher thresholds of hand sensitivity on the operated arms compared with the nonoperated arms. Cutaneous branches of the radial nerve are prone to injury during RFFF harvest. Donor site UBTF closure showed no significant benefit over STSG. However, our study was strengthened by comparing a homogeneous group for defect size and by using only validated instruments (VSS, MHQ, dynamometer, and monofilament testing). Other limitations of our study include its retrospective design, small sample size, and heterogeneity of defect sizes. Custom-made questionnaires and varying grading systems were often used. Our study is limited by significant selection bias. Patient recall tends to favor the inclusion of satisfied patients. However, our study was strengthened by comparing a homogeneous group for defect size and by using only validated instruments (VSS, MHQ, dynamometer, and monofilament testing). Other limitations of our study include its retrospective design, small sample size, and residual mean flap size difference between the 2 groups. The use of the nonoperated arm as a control is acceptable, although preoperative measurements on the operated arm in a prospective fashion should be undertaken in future studies.

Generally, we recommend the use of UBTF closure under the following conditions: (1) the flap size should not exceed 25 to 30 cm², (2) the long axis of the flap can be oriented transversely across the wrist, (3) the defect encompasses less than one-third of the wrist circumference, the shape of the flap should also be considered. The UBTF must be designed with its long axis placed transversely across the wrist (Figure 1). Flaps of up to 8 cm in length (long axis) were used for most patients in the series by Elliot et al. The width (short axis) of the defect should not exceed 4 to 5 cm; otherwise, UBTF rotation will require extensive undermining and applies excessive tension on the vascular pedicles. This can lead to ischemic complications ranging from marginal necrosis to complete loss of the flap. These issues are well known, although they are not often reported. Furthermore, the narrowest portion of the short axis has to be designed on the ulnar aspect of the defect (Figure 1), which facilitates primary closure. If UBTF closure produces excessive tension along the suture lines, the decision should be made to keep part of the defect uncovered by the UBTF and to harvest a small skin graft to close the residual defect. In this situation, the size of the residual defect can be further reduced by placing a purse-string suture, which allows for a 44% mean reduction in the defect size (Figure 3). Elliot et al. discussed the possible need for a skin graft when primary closure of the proximal forearm is not feasible. According to Bashir et al., proximal skin grafting can be avoided by performing a simple Z-plasty (Figure 3).

Other local flap techniques based on perforators from the ulnar artery have been described. Hsieh et al. used a bilobed flap to successfully close forearm donor sites of up to 8 × 8 cm in 10 patients. During elevation of the bilobed flap, 1 to 3 perforators from the ulnar artery were identified, with their most common location being 8 cm proximal to the pisiform. Shoab et al. described 5 patients whose donor sites were closed with an ulnar-based islanded V-to-Y flap. However, the 2 latter options (bilobed flap and V-Y flap) are somewhat more challenging than STSG or UBTF closure and should be used with caution. Juretic et al. proposed a shorter UBTF that allows for skin grafting to be performed more proximally over the muscle belly to avoid exposed tendons. None of these techniques have been compared with standard methods of forearm donor site closure.

Limitations of previous studies include lack of uniformity in evaluation tools, retrospective study designs, and heterogeneity of defect sizes. Custom-made questionnaires and varying grading systems were often used. Our study is limited by significant selection bias. Patient recall tends to favor the inclusion of satisfied patients.
ence, and (4) the forearm skin has good laxity on clinical examination. However, UBTF closure is not recommended in patients who have darker skin types or in those who are prone to hypertrophied scar formation.

In conclusion, the RFFF donor site carries significant functional and aesthetic morbidity. Donor site UBTF closure is an alternative method of closure for small donor site defects. Although the expected functional and aesthetic benefits of UBTF closure have not been established, there is a general trend toward better functional outcomes with its use, and further investigations are recommended.

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Author Contributions: Drs Jaquet, Enepekides, and Higgins had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Jaquet, Enepekides, and Higgins. Acquisition of data: Jaquet and Torgerson. Analysis and interpretation of data: Jaquet. Drafting of the manuscript: Jaquet. Critical revision of the manuscript for important intellectual content: Enepekides, Torgerson, and Higgins. Statistical analysis: Jaquet and Higgins. Administrative, technical, and material support: Enepekides and Higgins. Study supervision: Enepekides, Higgins.

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REFERENCES