CLINICAL ARTICLE

Reverse Posterior Interosseous Artery Flap for Reconstruction of the Wrist and Hand after Sarcoma Resection

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Objective: To report our experience of posterior interosseous artery flap reconstruction of the wrist and hand after soft tissue sarcoma resection.

Methods: Thirteen patients who presented to our institution for treatment of soft tissue sarcomas of the wrist and hand from February 2007 to January 2009 were prospectively enrolled. After tumor resection, the soft tissue defects were covered with posterior interosseous artery flaps. Relevant patient characteristics, results of creation of flap and functional outcomes were reviewed. Relevant clinical characteristics were recorded prior to surgery. The size, pedicle length and thickness of flaps were measured intraoperatively and complications evaluated two weeks after surgery. Functional outcomes and aesthetic results were evaluated 6 to 24 months after surgery, using Enneking's Musculoskeletal Tumor Society (MSTS) 93 functional scoring system.

Results: The patients' ages ranged from 14 to 82 years (54.92 ± 19.09 years), including six aged >65 years. Flap sizes varied from 5 cm × 3 cm to 8 cm × 5 cm. Flap survival rate was 100%. One patient had partial necrosis of the Z-shaped incision, which healed with routine wound care. Mean Musculoskeletal Tumor Society functional score was 27.31 ± 3.68 . Eleven patients were alive and disease-free at a mean follow-up of 36 months. One patient died of pulmonary metastases 18 months after surgery. One patient developed recurrence and underwent amputation 12 months after surgery.

Discussion: Reverse posterior interosseous flaps are reliable flaps for reconstruction of the wrist and hand after soft tissue sarcoma resection. They are suitable for elderly patients. The one-stage surgery and primary healing allow for timely postoperative adjuvant therapy following this type of reconstruction.

Key words: Posterior interosseous artery; Soft tissue sarcoma; Surgical flap; Wrist and hand

Introduction

Historically, amputation has been the main treatment for soft tissue sarcomas (STSs) of the limbs. Provided surgeons follow oncologic principles for resection, patients with spared limbs reportedly have the same survival as those whose limbs are amputated^{1,2}. Because the soft tissue defects after STS resection are extensive and variable, surgeons often utilize plastic surgery techniques to perform limb-sparing surgery^{3,4}.

Using flap transplants, we can cover the defect following limb-sparing surgery and achieve primary healing. This procedure allows for the timely initiation of postoperative adjuvant therapy. STS originating from the wrist and hand presents unique challenges. Amputation is undesired because of the special function requirements of hand. Conventional dermato-plasty was a common method to cover the defect after tumor resection. As a consequence, severe loss of function would

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happen frequently. Reconstruction of this area requires a reliable flap with a gliding surface to cover the exposed tissues^{2,5}. Posterior interosseous artery (PIA) flaps have been widely used in trauma surgery to reconstruct the wrist and hand⁶⁻⁸. The purpose of this study was to report our experience of PIA flap reconstruction of the wrist and hand after STS resection.

Materials and Methods

Patient Selection

The authors' institution gave permission for this study, all participants provided written informed consent and the institutional review board approved the study in writing. This study included 13 consecutive patients who presented to our institution with STSs of the dorsal wrist and hand from February 2007 to January 2009. Pathologic diagnosis was obtained by needle aspiration cytology or incisional biopsy. Five of the patients presented with recurrent tumor. No patient had distant metastases at the time of surgery. The patients' ages ranged from 14 to 82 years (54.92 ± 19.09 years), including six aged >65 years. Relevant patient characteristics are shown in Table 1.

Surgical Anatomy

The PIA arises from the interosseous artery, which is a branch of the ulnar artery. It crosses the upper border of the antebrachial interosseous membrane and descends between the supinator and abductor pollicis longus muscles, running along the axis from the lateral epicondyle of the humerus to the radial edge of the head of the ulna. Five to thirteen cutaneous branches arise from the PIA, mostly in the proximal half of forearm, and supply the skin of the dorsal forearm. The PIA anastomoses with the dorsal branch of the anterior interosseous artery and the dorsal carpal branch of the radial artery at a point 2.5 cm proximal to the radial edge of the distal radio-ulnar joint (DRUJ)^{7,9}. This vascular anatomy permits the surgeon to create a reversed flap from the dorsal forearm^{10,11}. Several vascular variations in this anatomical region have been described; however, these variations do not prevent use of the flap^{9,12-14} (Fig. 1).

Surgical Technique

A tourniquet and harmonic scalpel were used to reduce bleeding. Preoperative magnetic resonance imaging (MRI) was used to assess tumor mass, the required soft tissue defect and invasion of nearby tissues. A flap was designed on the dorsum of the forearm and a Doppler device used to ensure that the main perforators were in the center of the flap, after which the skin incision line and the boundaries of the flap were drawn (Fig. 2A).

After the tumor had been removed, negative resection margins were confirmed by assessment of frozen sections. The involved tendons, nerves, vessels, bone and joint were excised together with the tumor. No patient had defects of nerves, vessels, bone or joint that required reconstruction. Five patients underwent autologous tendon grafting for the tendon defects after tumor resection (Fig. 2B). Thereafter, the

TABLE 1 Relevant patient characteristics, the results of the flaps and functional scores

Patient(No.)	Sex	Age (years)	Diagnosis	Stage*	Defect size (cm)	Flap size (cm)	Adjuvant therapy	Complications	MSTS Functional scores	Recurrence
1	Male	68	Synoviosarcoma	III	4 × 2	5 × 3	Yes	No	28	—
2	Male	72	Malignant tenosynovial giant cell tumor	IIb	5 × 4	7 × 5	No	No	28	No
3	Female	47	Clear cell sarcoma	IIa	5 × 3	6 × 4	No	No	22	No
4	Female	36	Malignant fibrous histiocytoma	IIa	4 × 2	6 × 3	Yes	No	29	No
5	Male	32	Fibrosarcoma	Ib	4 × 2	5 × 3	No	No	30	No
6	Female	82	Epithelial sarcoma	IIa	5 × 4	6 × 5	No	Partial necrosis	30	No
7	Male	71	Angiosarcoma	IIb	5 × 4	6 × 5	No	No	29	Yes
8	Female	66	Leiomyosarcoma	IIa	6 × 4	8 × 5	Yes	No	21	No
9	Female	56	Fibrosarcoma	Ib	5 × 2	6 × 3	No	No	29	No
10	Male	65	Leiomyosarcoma	IIa	5 × 3	6 × 4	Yes	No	30	No
11	Male	58	Malignant fibrous histiocytoma	Ib	4 × 3	5 × 4	Yes	No	29	No
12	Male	14	Fibrosarcoma	IIa	6 × 4	8 × 6	No	No	30	No
13	Female	47	Synoviosarcoma	III	5 × 3	7 × 4	Yes	No	20	No

*Stage of tumor determined according to American Joint Cancer Committee/Union for International Cancer Control criteria. MSTS, Musculoskeletal Tumor Society.

Fig. 1 The muscles and vessels of the forearm.

previously delineated flap was created. Fine sutures were used to prevent the fascia and skin from separating during the dissection^{7,9,12}. After creating the flap, it was rotated to cover the defect (Fig. 2C). The donor site was sutured or skin grafted (Fig. 2D). No drain was left provided thorough wound hemostasis had been achieved.

Data Collection

Relevant clinical characteristics were recorded prior to surgery. The size, pedicle length and thickness of flaps were measured intraoperatively and complications evaluated two weeks after surgery. Functional outcomes and aesthetic results were evaluated 6 to 24 months after surgery, using Enneking's Musculoskeletal Tumor Society (MSTS) 93 functional scoring system for functional evaluation of reconstructive procedures after surgical treatment of tumors¹⁵. Each of six categories, namely pain, functional and emotional acceptance, hand positioning, dexterity and lifting ability, were assigned numerical values (0 to 5). The incidence of recurrence and survival were evaluated at follow-up (mean, 48 months; range, 18–62 months).

Results

The flaps ranged from 5 cm × 3 cm to 8 cm × 5 cm in size and were 0.54 ± 0.10 cm thick. The average pedicle length was 6.46 ± 1.27 cm. The mean operation time was 85.77 ±

16.81 min. The mean blood loss was 66.92 ± 20.97 ml. Flap survival was 100%. One patient had partial necrosis of the Z-shaped incision, which healed with routine wound care. We sutured the donor sites closed in eleven patients and used skin grafts in two cases. The donor sites healed by primary intention in all patients (Fig. 2E). We observed no posterior interosseous nerve palsy. Eleven patients were satisfied with the appearance of their wound and one found the appearance acceptable. One patient was dissatisfied with the cosmetic outcome after undergoing postoperative radiation therapy. We have presented the outcomes following flap reconstruction in Table 1. The mean MSTS score was 27.31 ± 3.68 (Table 1). Five patients received neoadjuvant chemotherapy with the doxorubicin (40–60 mg/m², day 1) combined with ifosfamide (2 g/m², day 1–5) for four cycles. One patient received postoperative radiation therapy, the radiotherapy dosage being 50 Gy. Eleven patients were alive and disease-free at a mean follow-up of 36 months (range, 18–62 months). One patient died of pulmonary metastases 18 months after surgery. One patient developed recurrent disease, underwent amputation 12 months after the initial surgery, and was alive at follow-up.

Discussion

The goals of treating STSs of the limbs are survival and preservation of a functional limb. Local recurrence is a risk factor for survival. Because the incidence of local recurrence is associated with the type of resection, negative resection margins (R0 resection) must be achieved^{1,3–5}. The soft tissue defects following extensive resection of STSs are very extensive. If adequate soft tissue coverage cannot be achieved, amputation is inevitable. In addition, adequate soft tissue coverage of the defect is necessary prior to initiation of adjuvant radiotherapy and chemotherapy. Versatile flaps are required for reconstruction after excision of STSs of the hands and wrists. Local flaps are insufficient to cover the large defects created by the extensive resection required. Abdominal flaps should not be the first choice for coverage because they do not conform to oncologic principles for treatment of malignant tumors. The shortcomings of free flaps include the complexity of the procedure, risk of total necrosis and their unsuitability for elderly patients. Pedicled island flaps are a reliable option for covering the hands and wrists after STS resection. The requirement for sacrifice of a main vessel has limited the use of radial artery forearm flaps and ulnar artery forearm flaps. Island flaps based on the distal cutaneous branch of the ulnar artery or radial artery spare the main vessel, but their short vascular pedicles and small size limit their use. Furthermore, there is also significant donor-site morbidity related to the scar^{16–18}.

Zancolli and Angrigiani were the first to describe the PIA flap¹⁹. The PIA flap can cover various defects of the hand and is a one-stage operation^{6,17}. The PIA flap is thin, pliable and has a reliable blood circulation. The main indication for the use of PIA flaps is reconstruction after hand injuries^{6,7}. In this study, we used PIA flaps to reconstruct defects of the dorsal wrist and hand after STS resection. Reconstruction of soft-tissue defects after malignant tumor resection not only provides functional

Fig. 2 This 47-year-old woman had stage IIb clear cell sarcoma of the right wrist; the insertion of the extensor pollicis longus tendon was within the tumor. We resected the tumor together with involved adjacent tissue and reconstructed the tendon defect using extensor indicis proprius transposition, following which we used PIA flap to cover the soft tissue defect. (A) Photograph of the forearm and hand and diagram showing skin incision and design of the flap. (B) Intra-operative photograph and diagram showing construction of the PIA flap. (C) Intra-operative photograph showing reversal of the flap is to cover the defect. (D) Photograph showing primary closure of the donor site. (E) The functional and aesthetic outcomes 12 months after surgery.

and cosmetic restoration but also leads to fewer complications and improves primary healing, allowing timely initiation of postoperative adjuvant therapy. As a vascular pedicle, the PIA is consistent and reliable; however, rare anatomical variations have been reported^{12,14}. No patients in this study had anatomical variations. A reliable vascular pedicle guarantees adequate

blood supply, avoids tissue necrosis and makes the dissection easier⁷. Provided there is no damage to the vascular pedicle, flap necrosis does not occur. When creating the flap, we avoided injury to the vascular pedicle by using direct visualization. We widened the pedicle fascia 2 cm to accommodate the vascular bundle. Moreover, we believe that a harmonic scalpel is superior

to electrocautery for reducing damage to the vascular pedicle. There are two possible explanations for partial necrosis: one is poor arterial blood supply to the margins of the flap and the second hematomas. We decreased the postoperative morbidity of this operation in several ways. First, we designed size of the flaps that extended 1–2 cm beyond the defect area, thus creating generous fascial flaps. Second, we made Z-shaped incisions to avoid pressure on the vascular pedicles. Third, we avoided hematomas by using a harmonic scalpel to achieve hemostasis. Using these techniques, we were able to perform the operation on six elderly patients. Only one elderly patient developed partial necrosis of the Z-shaped incision. The remaining patients had no local complications. We therefore believe that

PIA flaps are suitable for elderly patients. We also used this flap in a 14-year-old boy. Tanhas reported that the PIA flap can be used in children²⁰. A long vascular pedicle without loss of the main artery made the rotation easy. We transferred the flap to most of the dorsal aspects of the hand and wrist. Although the donor site defects must be extensive in oncological surgery, it is possible to suture directly in most patients because of the redundant skin of the dorsal forearm.

One of the limitations of the PIA flap is that it is not a sensate flap, which we believe is not as important for the dorsal hand and wrist. No patients in our study had a STS originating from the palm. Therefore, none of our patients required PIA flap reconstruction for defects of the palm.

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