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CLINICAL RESEARCH

Single Ray Amputation for Tumors of the Hand

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Abstract Single ray amputation after hand trauma or infection can result in good aesthetic and functional outcomes. The role of this procedure in the management of aggressive benign or malignant hand tumors has been described only in case reports and small case series. We retrospectively reviewed the records of all 25 patients who underwent single ray amputations at our center during a 10-year period; there were seven index, five middle, six ring, and seven small ray amputations performed. The minimum followup was 2 months (mean, 36 months; range, 2–120 months), with four patients having a followup of 1 year or less. No patients had local recurrences, although two patients had positive resection margins. One underwent repeat resection followed by radiotherapy. The other was treated with radiotherapy alone, as local tumor control would have required a hand amputation. Functional assessment based on the Musculoskeletal Tumor Society staging system showed an average of 27.5 (range, 21–30). Patients who underwent perioperative radiotherapy experienced a decrease in functional ability. Grip strength was an average of 66% (range, 38%–100%) of the contralateral side. Our study suggests single ray amputation for hand tumors has a low local recurrence rate and high functional scores. However, function can be compromised by radiotherapy and a decrease in grip strength by a mean of 34% is to be expected.

Level of Evidence: Level IV, case series. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research.

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Introduction

Although the role of single ray amputation for treatment of traumatic hand injuries and hand infection is well established [7, 14, 17, 19, 20], its functional and oncologic outcomes for management of hand tumors are not as well defined. Several variations in the procedure, when used for tumors, may affect the eventual outcome of surgery. For example, the adjacent interosseous muscle frequently is excised to achieve complete tumor clearance. Occasionally, the digital neurovascular bundles and tendons of adjacent digits must be sacrificed as well, with secondary reconstruction to restore function. Finally, perioperative radiotherapy may be required for large or high-grade tumors or when surgical resection margins are close, which is frequently the case in the hand [1, 11, 12, 21]. This will cause more fibrosis and stiffness of the hand, further affecting the range of motion, strength, and consequently, functional outcome. Ray amputation is an ablative and a limb-sparing surgery. Loss of the digit allows preservation of the hand and provides a good source of soft tissue cover from a fillet flap [13], and spare parts such as nerve, tendon, and even vessel grafts for secondary reconstruction, eliminating the need to use other donor sites. However, adequate resection is paramount, and at times, free tissue transfer from distant sites will be required instead.

Some authors report reasonable functional scores, grip and pinch strength, and high rates of return to work when performing single ray amputations as primary or secondary reconstructive procedures after hand trauma [7, 14, 17, 19, 20]. Many others focused on local recurrence and survival rates from treatments of aggressive benign and primary malignant hand tumors, and metastases to the hand [1–3, 5, 6, 8, 10–12, 15, 16, 18, 21]. None of these reports have looked specifically at local recurrence rates or the functional outcome after single ray resection for tumors.

We therefore asked the following questions: (1) Could we achieve negative margins with low local recurrence rates when performing single ray amputations for aggressive benign and malignant lesions of the hand? (2) Would more extensive surgery as compared with a standard posttraumatic ray amputation substantially compromise the functional outcome of the hand assessed using the Musculoskeletal Tumor Society (MSTS) score and grip strength? (3) Were there any factors (for example, patient age, affected digit, or use of perioperative radiation) that resulted in a lower MSTS score? We presumed we could achieve negative margins with low local recurrence rates while preserving good aesthetic appearance and functional use of the hand.

Materials and Methods

We retrospectively reviewed the records of all 25 patients who had a single ray amputation of the hand during the 10 years from 1997 to 2007 at our center by one surgeon (EAA). We excluded patients with lesions affecting the thumb, as the thumb contributes more to overall hand function and, therefore, its loss would be far more disabling than that of any other ray. Furthermore, no isolated first ray amputations were performed without some reconstruction to restore function. We focused on patients who were at least 2 years postsurgery to allow time for hand function to stabilize and to enable assessment for local recurrence. The minimum followup for all the patients was 2 months (mean, 36 months; range, 2–120 months). Six patients were lost to followup at a mean of 11 months (range, 2–24 months), whereas another five died during this period and had a mean followup of 10 months (range, 4–12 months).

We performed seven index, five middle, six ring, and seven small single ray amputations (Table 1). Surgery was performed on the dominant hands of nine patients and the nondominant hands of the other 16 patients. The mean age of these patients at the time of surgery was 48.8 years (range, 8–86 years). Eighteen patients had malignant soft tissue lesions, four had metastasis to the hand (three lung, one renal), two had giant cell tumors of the bone, and one had a malignant primary bone sarcoma. One patient with a primary malignant soft tissue tumor had metastatic disease on presentation. Ten patients underwent postoperative radiotherapy, two for positive margins and eight for close margins. Eight patients required the use of flaps to close the wound, two had transposition flaps, five had fillet flaps, and one had a free vascularized skin flap. Complete reconstruction was performed in many patients after tumor resection, when deemed appropriate, with flaps, tendon, and nerve grafts using spare parts from the amputated digit wherever possible. Only rarely were grafts taken from distant sites. This minimized donor site morbidity.

Preoperative resection was planned with the help of high-resolution MRI scans (Fig. 1). Patients selected for single ray amputations were (1) those with lesions that could be seen on imaging to affect the bone (metacarpal or proximal phalanx) of only one ray and the soft tissue around it or (2) those with soft tissue lesions that required a wide resection that would result in substantially impaired function of the digit. Once a tumor had invaded the bone of the adjacent ray or involved both neurovascular bundles of the adjacent digit, a more radical resection (with a double ray amputation or more) would be required. This was performed for four patients during the same period.

We performed tumor excision through a volar Z-Brunner type incision and dorsal longitudinal extension along the digit, incorporating the previous biopsy incision (Fig. 2). Whenever required, a fillet flap was raised from the amputated ray based on the volar digital arteries. The extensor mechanism then was incised proximally, the adjacent interosseous muscles incised, and dissection performed around the tumor with the interosseous muscles taken as a margin. Often, subperiosteal dissection on the adjacent metacarpal was required. We made the volar incisions and identified the neurovascular bundles. Where necessary, the common digital neurovascular bundles were sacrificed to completely excise the tumor. The intermetacarpal ligaments then were transected and the flexor tendons transected proximally. We made bone cuts through the base of the metacarpal or disarticulated the ray through the carpometacarpal joint. Circumferential dissection then was performed to ensure complete en bloc removal of the tumor (Fig. 3). For central ray amputations, we then repaired or reconstructed the remnants of the adjacent intermetacarpal ligaments, ensuring appropriate rotation of the digits. The skin flaps were fashioned and closed over a drain either primarily or with the fillet flap (Fig. 4), which was performed in five patients. Ray transposition was not performed for any of the patients.

Some considerations were specific to the ray being amputated. During small finger ray amputation, special attention must be paid to the ulnar artery and nerve as it winds around the hook of the hamate. Similarly, the radial

Table 1. Summary of patients

Patient	Age (years)	Gender	Ray	Histology	Tumor	Radiation	AJCC stage	Margins	Followup (months)	MSTS score	Grip (%)	Current status
1	8	Female	IF	STS	Primary	No	2	Negative	96	30	40	NED
2	51	Male	IF	NSCLC	Metastasis	Yes	4	Negative	118	27	NA	DOD
3	68	Female	IF	STS	Primary	No	2	Negative	24	27	80	NED
4	75	Male	IF	STS	Recurrent	No	2	Negative	12	29	NA	NED
5	79	Female	IF	STS	Recurrent	Yes	2	Positive	12	25	NA	DOC
6	80	Male	IF	STS	Primary	No	2	Negative	24	24	NA	NED
7	73	Male	IF	NSCLC	Metastasis	No	4	Negative	2	NA	NA	DOD
8	27	Female	MF	GCT bone	Primary	Yes	NA	Negative	60	29	NA	NED
9	37	Male	MF	Sweat gland carcinoma	Recurrent	No	4	Negative	12	27	NA	DOD
10	39	Male	MF	STS	Recurrent	Yes	2	Negative	36	28	NA	NED
11	51	Female	MF	STS	Primary	Yes	1	Negative	4	30	94	NED
12	72	Male	MF	NSCLC	Metastasis	No	4	Negative	12	29	NA	DOD
13	27	Female	RF	STS	Primary	No	2	Negative	24	29	100	NED
14	29	Female	RF	GCT bone	Primary	No	NA	Negative	33	29	71	NED
15	40	Male	RF	Chondrosarcoma	Primary	Yes	1	Negative	120	30	96	NED
16	41	Female	RF	STS	Primary	No	2	Negative	6	28	NA	NED
17	49	Female	RF	STS	Primary	No	2	Negative	24	26	38	NED
18	51	Female	RF	STS	Primary	No	2	Negative	24	28	93	NED
19	12	Female	LF	STS	Recurrent	No	2	Negative	66	28	67	NED
20	27	Female	LF	STS	Primary	Yes	2	Negative	29	21	NA	NED
21	33	Female	LF	STS	Primary	No	2	Positive	66	25	NA	NED
22	38	Male	LF	STS	Primary	Yes	2	Negative	68	28	70	NED
23	61	Female	LF	STS	Primary	Yes	1	Negative	14	30	NA	NED
24	66	Female	LF	STS	Primary	Yes	1	Negative	6	27	NA	NED
25	86	Female	LF	RCC	Metastasis	No	4	Negative	12	27	NA	DOD

AJCC = American Joint Committee on Cancer; MSTS = Musculoskeletal Tumor Society; IF = index finger; MF = middle finger; RF = ring finger; LF = little finger; STS = soft tissue sarcoma; GCT bone = giant cell tumor of the bone; NSCLC = nonsmall-cell lung cancer; RCC = renal cell carcinoma; NA = not available; NED = no evidence of disease; DOD = dead from disease; DOC = dead from other causes.

Fig. 1 MRI shows a soft tissue sarcoma (liposarcoma) in the first web space and extending close to the third metacarpal.

Fig. 2 The incision was planned incorporating the previous biopsy track.

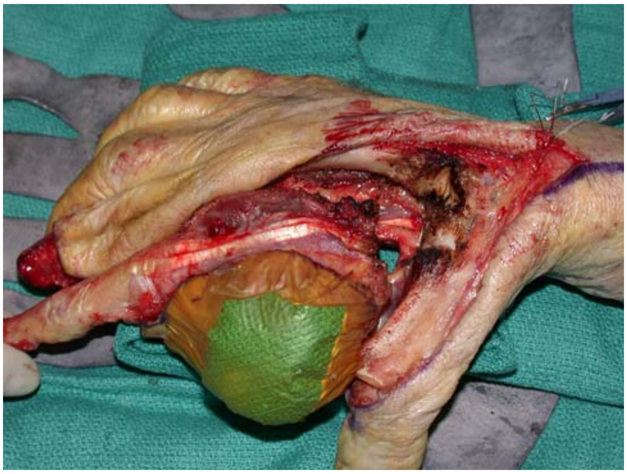

Fig. 3 An extended second ray amputation was performed, with circumferential dissection to ensure complete en bloc removal of the tumor.

Fig. 4 After the extended second ray amputation, the wound was closed with a fillet flap.

artery must be protected as it crosses the base of the second metacarpal. For the central digits, the deep motor branch of the ulnar nerve and deep arch should be protected during the osteotomy at the base of the metacarpal or disarticulation through the carpometacarpal joint.

Patients stayed overnight in the hospital and were discharged the day after surgery after range of motion therapy was initiated by the surgeon. They were reviewed on the tenth postoperative day when stitches were removed, and hand rehabilitation continued under the supervision of a hand occupational therapist.

Patients were reviewed at 6 weeks, 3 months, and then every 3 months during the first year, every 4 months for the next 2 years, and every 6 months during the fourth and fifth years. Hand function was assessed when we believed it had stabilized, on average 6 months after surgery, using the MSTS score [4]. Grip strength also was measured at this time using a Baseline® Hydraulic Hand Dynamometer (Fabrication Enterprises Inc, Irvington, NY), although these data were recorded in only 10 of the 25 patients. Chest radiographs were performed at these visits and CT scans of the chest were taken yearly.

Results

Of the 25 patients, five died from disease (including the four patients with metastatic lesions to the hand and one with a primary lesion in the hand who had distant metastasis at the time of surgery), one died from other causes, and 19 remained completely disease-free (Table 1). Two patients had positive resection margins. One underwent repeat resection to negative margins followed by radiotherapy and is currently disease-free 4 years after surgery. The other was treated with radiotherapy alone, as local surgical control would have required a hand amputation, which was refused by the patient; she died from nondisease-related causes 18 months after ray amputation. None of the patients had local recurrence.

We observed no differences in function between (1) amputation performed as a primary tumor excision versus excision of a locally recurrent tumor, (2) flap versus primary wound closure, (3) amputations of different rays, or (4) surgery on the dominant versus nondominant hand. The average MSTS score was 27.5 (range, 21–30). We measured grip strength in 10 patients, with an average of 66% (range, 38%–100%) of the contralateral side.

Slightly lower MSTS scores were seen in patients who had received radiotherapy than in those who did not (average 26.4 versus 28.5, respectively). The age of the patient at the time of surgery had no impact on the MSTS score.

Discussion

We conducted this retrospective review of patient records for those who had single ray amputation for treatment of aggressive local and malignant tumors to answer the following questions: (1) Could we achieve negative margins with low local recurrence rates when performing single ray amputations for aggressive benign and malignant lesions of the hand? (2) Would more extensive surgery as compared with a standard posttraumatic ray amputation substantially compromise the functional outcome of the hand assessed using the MSTS score and grip strength? (3) Did any factors (for example, patient age, affected digit, or use of perioperative radiation) result in a lower MSTS score? We presumed we could achieve negative margins with low local recurrence rates while preserving good aesthetic appearance and functional use of the hand.

This study is first limited by its small size. However, small size is inevitable given the rarity of tumors of the hand that require ray amputation. As the small number of patients limits our ability to perform meaningful survival analyses or subset analysis, we have described certain trends instead—for example, lower MSTS scores in patients who received perioperative radiation to the hand. Second, single ray amputations of patients with tumors vary more widely than do those performed in the trauma setting.

We managed to achieve negative resection margins in 23 of the 25 patients. None of our patients had local recurrence during the period of this study. We believe surgical planning was greatly helped by high-resolution MRI scans of the hand. Our standard approach to managing patients who had close surgical margins was to use postoperative radiotherapy, even though we anticipated this would compromise functional outcome. When resection margins were positive, repeat resection to clear margins followed by radiotherapy was performed in one patient and radiotherapy alone in the other. The former option offers the best chance for local control of the tumor, although it may not make a difference to overall survival in the setting of soft tissue sarcomas [9, 11].

Good functional results reflected in the high mean MSTS score of 27.5 were achieved for patients who underwent single ray amputation for excision of tumors of the hand. The results compare favorably to those of a recent study that also included ray transposition and in which a mean MSTS score of 60% (18) was reported [16]. However, that group also included a patient who underwent ray amputation of the thumb followed by index ray amputation. Loss of the thumb ray expectedly resulted in a lower MSTS score that brought the mean score lower as well. Grip strength compared with the nonoperated side was only slightly poorer than that found in patients who underwent ray amputation in the trauma setting (66% versus 72% and 73%) [14, 19], and was equivalent for those who had concurrent ray transposition [7]. This most likely was attributable to the more extensive resection, including the interosseous muscle of adjacent digits, that was required for adequate tumor clearance.

Patients who had perioperative radiotherapy to the hand had somewhat lower MSTS scores, although the difference in the scores was not large and likely would not be clinically meaningful. Furthermore, as this group of patients generally had larger tumors and required more extensive surgery, it is uncertain if the poorer functional outcome was attributable to radiotherapy alone or a combination of factors. We were unable to identify any other factors having an effect on the MSTS score.

Surgical treatment options for malignant hand tumors include en bloc excision, partial amputations (single or multiple ray), or complete hand amputations. The first option allows preservation of all digits but may require multiple donor tissues for reconstruction. The more donor tissue required, the higher is the risk for donor site morbidity. Hand amputation gives the best tumor clearance but should be performed only when negative margins and reasonable retention of function are not possible. Partial hand amputations, in the form of a single or double ray amputation, offer a good oncologic solution with function superior to more proximal level amputation. Single ray amputation is an ablative and reconstructive surgical technique that has good oncologic functional and aesthetic outcomes. The amputated digit also can serve as a donor site for a fillet skin flap and nerve, vessel, and tendon grafts. In light of the excellent tumor control and good functional results, this technique should be considered when managing patients with benign tumors with metastatic potential or malignant tumors of the hand.

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