A Novel Approach to Ray Resection of the Hand

Brendan MacKay, MD, * Hillary Wall, MS, * Amanda Weaver, MS, † Tyler Sexson, BS, † Jon Wall, MD, * Matthew Blue, MD, * Marcus Doughty, BS †

Department of Orthopaedic Surgery, Texas Tech University Health Sciences Center, Lubbock, TX
Sand Hills Physical Therapy, North Platte, NE
Great Plains Health Sports and Therapy Center, North Platte, NE

Surgical Technique

Ray resections have been a viable treatment option for patients with tumors, trauma, infection, vascular insufficiency, or other abnormalities of the hand since the procedure was described in the 1920s. The creation of a functional hand after central ray resection presents unique technical challenges: insufficient closure of the gap between the metacarpals bordering the resected ray can produce an enlarged space between remaining digits and potentially cause digital malrotation, both of which negatively affect hand function. The goal is to make the space between resulting fingers as close to normal as possible. A number of procedures were described to address this issue, but unfortunately, they can be technically onerous and may require prolonged immobilization, the use of internal hardware, or the use of temporary hardware requiring removal.

We describe a technique for amputation of the affected ray at the proximal metacarpal metadiaphyseal porion by completely resecting the fourth metacarpal and transposition of the adjacent metacarpal to the height of the translocated digit. Carroll initially described this procedure with transposition of the adjacent metacarpal to the metacarpal base of the amputated central ray. This immediately closes the resultant interdigital space created by the ray resection, allows the surgeon more control of rotation at the osteotomy site, maintains integrity of the carpometacarpal ligaments, and controls the height of the translocated digit. Carroll initially described this procedure with transposition of the adjacent metacarpal to the metacarpal base as well as transposition of the index metacarpal to the capitae with arthrodesis. Unfortunately, this technique proved to have its own complications, including loss of motion, nonunion, rotational and angular malunion, protrusion of the osteotomized metacarpal stump, and stiffness affecting pinch grip caused by adherence between the extensor tendon and osteotome site.

Le Viet attempted to improve on Carroll’s technique of transposition by completely resecting the fourth metacarpal and translocating the fifth metacarpal using an intercarpal wedge-shaped osteotomy, followed by capitate and hamate arthrodesis. Advantages of this technique include avoiding convergence, maintaining of ulnar integrity, preserving the fifth carpometacarpal joint, and not changing the action of the interossei. Complications arising from Le

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Corresponding author: Brendan MacKay, MD, Department of Orthopaedic Surgery, Texas Tech Health Sciences Center, 3601 4th Street, Mail Stop 9436, Lubbock, TX 79430-9436.
E-mail address: brendan.j.mackay@ttuhsc.edu (B. MacKay).

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Viet’s technique included transient wrist pain that usually subsided after 6 weeks, pseudoarthrosis, malrotation, and one transient case of carpal tunnel syndrome. This may come from disruption of the carpal row’s integrity with carpal osteotomy. Le Viet also noted the substantial learning curve required with this technique.

In an effort to mitigate the functional and aesthetic shortfalls brought about by these techniques, alternative approaches to central ray resection have been developed that do not include transposition. Steichen and Idler\textsuperscript{7} described a technique using nonabsorbable suture and fine-tuning with a dermodesis to reconstruct the adjacent deep transverse intermetacarpal ligaments (DTIL). The base of the metacarpal was left in situ. Although they reported good function and cosmetic results with no late scissoring or malrotation, others later criticized that gap closure and malalignment persisted.

Lyall and Elliot\textsuperscript{8} described a long finger ray resection in which the base of the metacarpal was removed to reduce the intermetacarpal space and limit scissoring. They suggested that removing the metacarpal base between the index and ring metacarpals allows both to move in conjunction with greater ease.

Gong et al\textsuperscript{9} later described a technique similar to that of Steichen and Idler,\textsuperscript{7} in which the DTIL can be reconstructed using a free tendon graft.

Iselen and Peze\textsuperscript{5} presented a technique that includes removal of the metacarpal base and a closing wedge osteotomy of the capitate for middle finger ray resection. Although this method produced normal range of motion with no evidence of nerve compression, reduction in hand width resulted in loss of about one-third of grip strength.

Most recently, O’Brien and Singh\textsuperscript{1} developed a technique that addresses gap closure and malrotation simultaneously. After the metacarpal is cut at its base, a suture button device is used to control rotation of the adjacent metacarpal necks and close the intermetacarpal gap.
Surgical Anatomy

Any time a surgeon intends to alter the complex anatomical structure of the hand considerably, such as in a ray amputation, it is important to consider the effects it will have on overall function. For this, it is helpful to divide the hand into its 3 functional units: (1) an opposable thumb, (2) the index and middle fingers for pinch, and (3) the ring and little fingers for grip (Fig. 1A). With a central ray resection (namely, the rays of the index or middle fingers), the decrease in the width of the palm results in a subsequent decrease in grip strength, whereas preservation of the palm width with partial amputation can result in small objects falling through the space created by the missing digit. This amputation stump may also be subjected to repeated trauma; in response, it may become a source of pain, and some may also consider this gap to be cosmetically less appealing.

Another important anatomic structure to consider is the DTIL. This ligament connects the metacarpals and keeps them in plane throughout flexion and extension of the digits (Fig. 1B). Without this stabilization, forces across the metacarpals, particularly flexion, would cause gapping or scissoring of the digits. Because central ray amputations violate this normal anatomic relation, scissoring is one of its most common complications. This can be avoided by adequate repair of an intact DTIL or reconstruction. Even with careful ligamentous repair, rotational deformities may be present. The use of skin to make rotational adjustments after DTIL repair has been described in the literature and may be an underemployed resource in creating an anatomic cascade of the remaining digits.

Although these anatomic considerations are all well-acknowledged in currently described techniques, alterations of the bony anatomy seem to be where most techniques differ.

Indications and Contraindications

Ray resection amputations have been used for severe deformity of a digit, tumors requiring resection, traumatic injuries, and infectious disorders. Single ray amputations have better cosmetic appeal than a partial finger amputation; however, they have been shown to have decreased grip and pinch strength compared with amputations at the level of the proximal phalanx. Despite the challenges that accompany ray resection, this procedure does much to restore normal hand functionality. This demonstrates the need for a collaborative decision between the surgeon and the patient concerning the best approach to treatment. Patients should be engaged in conversations to determine the importance of functional and aesthetic outcomes before proceeding with a course of treatment.
In ray resections with transposition, surgeons have the choice of K-wires or plating for stabilization. Plating is more expensive, but the implant may be retained. K-wires are removable, but they are associated with pin track complications. In cases of gap closure without transposition, a suture button device has been described in the literature to maintain alignment. The device of load ligamentous repairs, but time to failure of the suture button is a concern, and the adjacent metacarpals are put under undue stress by inward pulling forces. Techniques that modify the carpus have also been reported; however, it is desirable to avoid carpal disruption when possible. The technique we describe addresses the shortcomings of these methods and may be useful in most amputations involving a central ray (Table 1).

**Surgical Technique**

We currently use a supine position with a hand table and tourniquet and prefer regional anesthesia with or without associated sedation. Existing techniques describe a single circumferential incision with surplus skin left distally to trim later in the procedure. However, we employ large skin paddles on both sides, allowing for intraoperative soft tissue and skin rearrangement to assist in rotational control and improve cosmesis (Fig. 2).

After the metacarpal is osteotomized and interosseous tendons have been divided, dissection is performed to identify sensory branches of the digital nerve. The digital nerves are then transected proximally, maintaining sensory branches to the remaining skin paddles when possible, and then buried in the interosseous muscle to protect subsequent neuromas from external trauma.

Our modification to the classic technique involves adding a closing wedge to the remnant of the metacarpal base using a sagittal saw (Fig. 3). Caution is taken to ensure that the cut does not transect the most proximal cortex.

Gentle pressure is then applied from both the radial and ulnar directions to close the wedge effectively (Figs. 4, 5). If closure of the osteotomy is inadequate or a fracture causes instability in the closure, suture can be used through bone tunnels to hold the edges of the osteotomy together (Fig. 6).

The intermetacarpal ligaments are then cut as close as possible to the resected metacarpal (Fig. 7) to allow pants-over-vest approximation that will determine the amount of ligament to resect. Once this is completed, attention is turned toward repairing the intermetacarpal ligament with interrupted sutures.

The final step is meticulous dermoplasty to recreate an anatomic and aesthetically pleasing web space as well as assist in controlling the alignment and rotation of the remaining fingers. The dorsal or volar skin may be tensioned to ensure that the cascade of fingers is correct. Stay sutures and/or towel clips are used to adjust tension. Once rotation is correct, the skin is resected, the incision is closed, and stay sutures are removed.

Postoperative nerve blocks are used for pain control, and a volar orthosis and sterile dressing are placed, allowing flexion of the remaining fingers at the metacarpophalangeal joints. Both of our
cases were outpatient procedures, and patients went home the same day. Both patients remained in a plaster volar resting orthosis for 1 week. At that time, the orthoses were removed and the patients were treated with local wound care, a compressive dressing, and swelling control.

Two certified hand therapists managed the patients’ postoperative rehabilitation. Ultrasound and thermal modalities were used in conjunction with soft tissue massage for scarring. The patients attended therapy twice per week for 6 weeks beginning 1 to 2 weeks after surgery. At these visits, manual and active stretching were performed to increase range of motion, and iontophoresis was used to decrease swelling. Strength exercises were initiated between 2 and 3 months after surgery.

Case Illustrations

Both patients required reconstruction as a result of bony malignancy. In cancer patients, the use of implants, hardware, or both is avoided when possible, because these patients may be especially vulnerable to complications associated with hardware failure. Operative treatment in both cases was elective, and there was no trauma to the adjacent structures. These patients were relatively young and highly active; one was a tradesman. As such, return to normal activity was given high priority in both cases.

Patient 1

Patient 1 was a middle-aged man referred for evaluation of a digital squamous cell carcinoma located on the left middle finger, which had failed medical management (Fig. 8). The patient was a plumber and desired to return to full activity after surgical resection of the cancer. After discussion with the patient, it was decided that he would benefit from central ray resection using the technique described earlier.

Two weeks after surgery, the patient showed near full range of motion to the digits with some difficulty in terminal extension. He was neurovascularly intact. At 6 weeks’ follow-up, the patient had full range of motion of the digits with improved hand function and strength (Fig. 9). Grip strength at position 2 of a Jamar hand dynamometer (Sammons Preston Rolyan, Bolingbrook, IL) of the operative hand was 60 lb, compared with 102 lb of grip strength in the dominant, nonsurgical hand. At 11 weeks’ follow-up, the patient had returned to work and noted full function of the affected hand with no perceived deficit. He had some pain associated with the prominence of the scar in the palm. At 5 months’ follow-up, the patient noted no pain, had returned to full activity, and was pleased with the result of the procedure. X-rays showed that the closing wedge in the base of the metacarpal had healed with acceptable alignment (Fig. 10). Two years after the operation, the patient was evaluated by his hand therapist. Grip strength at position 2 of a Jamar hand dynamometer of the operative hand was 90 lb, compared with 102 lb of grip strength in the dominant, nonsurgical hand.

Figure 7. Diagram showing where to make intermetacarpal ligament cuts when resecting the ray.

Figure 8. Patient 1 immediately after surgery.
hand. In addition to functional improvement, the patient was satisfied with the aesthetic outcome.

Patient 2

Patient 2 was a middle-aged man referred for evaluation of what was thought to be a chronic wound at the end of the left middle finger (Fig. 11). Surgical biopsy determined this lesion to be an epithelioid sarcoma. Because wide resection is the reference standard of treatment, we decided to proceed with ray resection using the technique described earlier, as well as sentinel lymph node biopsy. Although no additional measures were taken to secure the closed wedge in patient 1, K-wire holes through the metacarpal remnant were made and the wedge was tied together with suture (Fig. 6).

The patient was observed in the office and attended occupational therapy for 3 months after surgery with no surgical complications. At 3 weeks’ follow-up, he had some swelling and did not have complete digital range of motion (Fig. 12). By 2 months after surgery, the patient had complete range of motion (Fig. 13). At 3 months’ follow-up, the patient had full range of motion and no scissoring and had returned to work activities with no pain (Fig. 14). At the last therapy visit, he had 80% grip strength compared with the contralateral hand. The patient was lost to follow-up after 3 months.

Pearls and Pitfalls

- We recommend, as with other bony osteotomies, that the cut made with the sagittal saw or osteotome be left incomplete and that pressure applied from the radial and ulnar sides of the hand be used to complete the fracture using the osteotomy site as a hinge.
- When making the initial incisions to create skin paddles, leave ample tissue for adjustments that may be needed at the time of...
closure. Further resection is always an option, so leave extra tissue to allow for intraoperative templating.
- As mentioned, if the osteotomy site is unstable or was completely cut through, bone tunnels with suture can be used to hold the edges together. Once this is completed, as stipulated by other techniques, meticulous attention must be payed to restoration of the DTIL as well as the dermoplasty to achieve the desired aesthetic result and alignment of the digits.
- After resection of the metacarpal, it may be necessary to resect more dorsal or volar tissue to help align the residual digits, because rotation is often difficult to control. Resecting as little ligament as possible when removing the metacarpal affords the flexibility necessary to make these adjustments during surgery.
- Although the nerve transposition technique previously described is commonly used to reduce neuroma exposure, recent developments such as nerve capping have been used to
Figure 12. Patient 2 at 3 weeks after surgery.

Figure 13. Patient 2 at 2 months after surgery.
prevent neuroma formation in transected digital nerves with no terminus. In addition to capping, a technique known as “nerve to nowhere,” in which the distal end of a nerve is routed proximally without neurorrhaphy, has also been reported in the literature. A third method of neuroma prevention involves relocation of nerves to proximal bone or muscle targets. None of these techniques were used in either case we describe, but they may warrant consideration for future treatment of ray amputations.

Complications

No complications were reported in either of the cases we described.

Conclusion

Standard techniques for central ray resections may fail to produce postoperative outcomes that give patients their desired function, aesthetic result, or both. By creating a wedge in the preserved metacarpal base, our technique simplifies previously published techniques and helps achieve postoperative goals with minimal additional disruption to the patient’s anatomy. The cases described here serve as representative examples of the effective use of our technique in ray resections of central digits. It is hoped that they will help other surgeons with this potentially challenging surgery and further validate this technique’s utility.

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