Chapter 38 Foot and Ankle Amputations: Ray Resections

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BACKGROUND

- Malignant tumors of the foot present a significant and formidable challenge to the orthopaedic oncologist due to the foot's unique function and anatomic peculiarities.
- The foot is uniquely adapted for bipedal motion and as such is essentially a tripod. The tripod is basically formed by the first ray, the fifth ray, and the calcaneus and is supported by the osseous configuration of bones in the midfoot that form a Roman arch, which in and of itself is inherently stable.
- Both bone and soft tissue contribute to the structure and function of the foot. Furthermore, the foot is composed of compact compartments that are interconnected by nerves and vascular structures. Complete resection (wide local excision) of osseous structures of the foot is difficult because of the interruption of these complex anatomic relationships, which afford stability to the foot, in addition to the interconnected compartments. Malignant tumors of bone are rare in the foot and rarer still in locations distal to the metatarsophalangeal joints.[3,5–9] Many of these tumors are treated with amputations.
- In the senior author's experience of foot and ankle tumors in 153 cases, 31 amputations were performed (**FIG 1A**). Fortunately, tumors distal to the metatarsophalangeal joint can be treated by amputation through the metatarsophalangeal joint with minimal disruption to function. The only exception is the first ray, which typically bears 50% of the weight with toe-off during each gait cycle. Therefore, preservation of as much proximal phalanx as possible is important to optimize this important structure.

INDICATIONS

- Tumors involving the toe or metatarsal bone are rare. Primary tumors affecting the foot, including osteosarcomas, have a low incidence.[1,2,7] Metastatic tumors of the foot are also rare.[5,11] The most common sites of primary tumors are lung, kidney, and colon.[5]
- In the senior author's experience of 153 foot and ankle tumors, 73 cases were bony (**FIG 1B**); of these, 7 cases involved the metatarsals (**FIG 1C**). The indications for ray resections are tumors involving the toe or metatarsal bone. Benign tumors make up the majority of these lesions.[6]
- **FIGURE 1D** shows the distribution of benign versus malignant diagnoses. The malignant lesions include metastatic disease, primary bony tumors, and soft tissue tumors.

ANATOMY

- The tripod is basically formed by the first ray, the fifth ray, and the calcaneus and is supported by the osseous configuration of bones in the midfoot that forms a Roman arch, which in and of itself is inherently stable.
- These bones are supported by ligamentous structures as well as tendons that help preserve the arch and support foot function. For this reason, resections of the first and fifth rays typically result in significant alterations in function, especially the first ray. The resulting forces after resection of the first ray result in transfer to the lesser metatarsals, which are ill adapted to structurally support the weight of the body, resulting in transverse metatarsalgia.
- These structural alterations can be mitigated in part by the judicious use of orthotics, such as a medial heel wedge to transfer the forces farther lateral or the use of a metatarsal bar, which will more evenly distribute the weight across the lesser metatarsals. Resection of the fifth ray is relatively easily compensated for by creating an orthosis that transfers the forces medially; thus, a lateral heel wedge is beneficial.
- Resection of the middle rays results in insignificant loss of function and acceptable cosmesis. The only net result is narrowing of the forefoot, which can be easily compensated for with shoe modifications.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with tumors of the toe or metatarsal present with pain and mass. The mass may be small and chronic. It may appear with an injury.
- Physical examination (Table 1) will reveal a tender mass localized to the toe or metatarsal. There may be associated swelling. If a sensory nerve overlies the mass, there may be paresthesias.

IMAGING AND OTHER STAGING STUDIES

- Preoperative studies include plain radiographs of the foot, including anteroposterior, lateral, and oblique views. If the ankle joint is involved, then anteroposterior and mortise views are obtained.
- MRI is important to evaluate the amount of involvement of the metatarsals to determine the level of amputation. The case in **FIGURE 2** shows cortical thickening of the second metatarsal. The clinical photographs show increased space between the metatarsals. MRI shows the soft tissue involvement. The lesion was found to be benign.

SURGICAL MANAGEMENT

- The goal of the surgical procedure is to remove the tumor with adequate margins.
- A long plantar flap is important for a sturdy end-bearing stump.
- The bony edges should be smooth and beveled if possible.
- Myodesis is helpful to pad the end of the stump.
- *Figure 2* shows pigmented villonodular synovitis (PVNS) localized to the plantar aspect of the first metatarsal head. The clinical photographs show the mass. MRI shows the soft tissue involvement. Intraoperative photograph shows resection of the tumor.

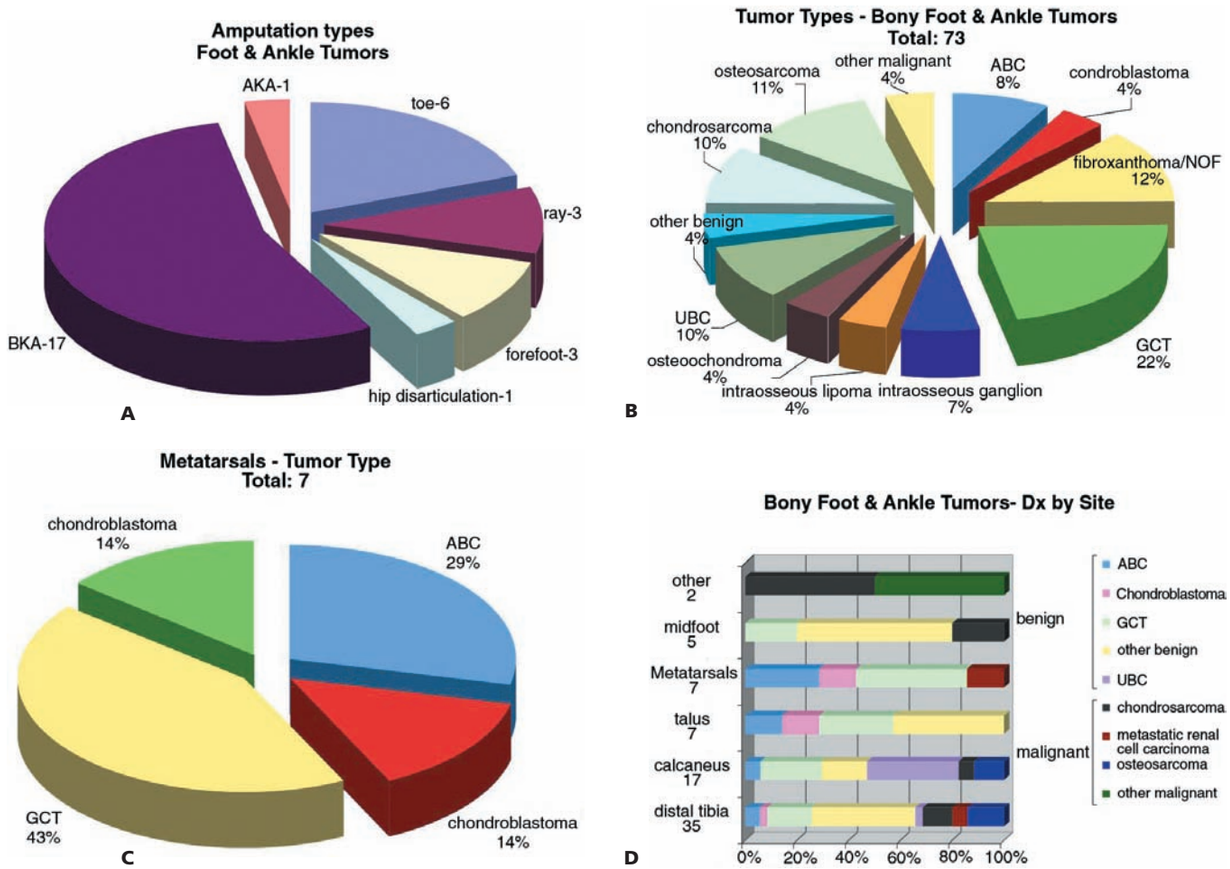


FIG 1 • A. Distribution of types of amputations for 153 tumors of the foot and ankle (n = 31). **B.** All diagnoses of bony tumors of the foot and ankle (n = 73). **C.** Diagnoses of metatarsal tumors (n = 7). **D.** Distribution of bony tumors of the foot and ankle by diagnosis and site (n = 73).

Table 1 Physical Examination Methods

Examination	Technique	Significance
Inspection	Evaluate the lower extremity with the patient undressed from the knees.	Examination of both extremities allows for comparison to identify abnormalities.
Palpation	Gentle and deep palpation of the mass or area of pain	Evaluates tenderness of the mass; evaluates whether the mass is mobile or fixed
Range of motion	Observe passive and active range of motion of the foot and ankle.	Identifies joint involvement with tumor
Vascular examination	Palpate dorsalis pedis and posterior tibia arteries.	Evaluates vascularity of the extremity and whether there is tumor involvement
Neurologic examination	Evaluate motor strength and sensation to light touch.	Evaluates involvement of muscles and sensory nerves

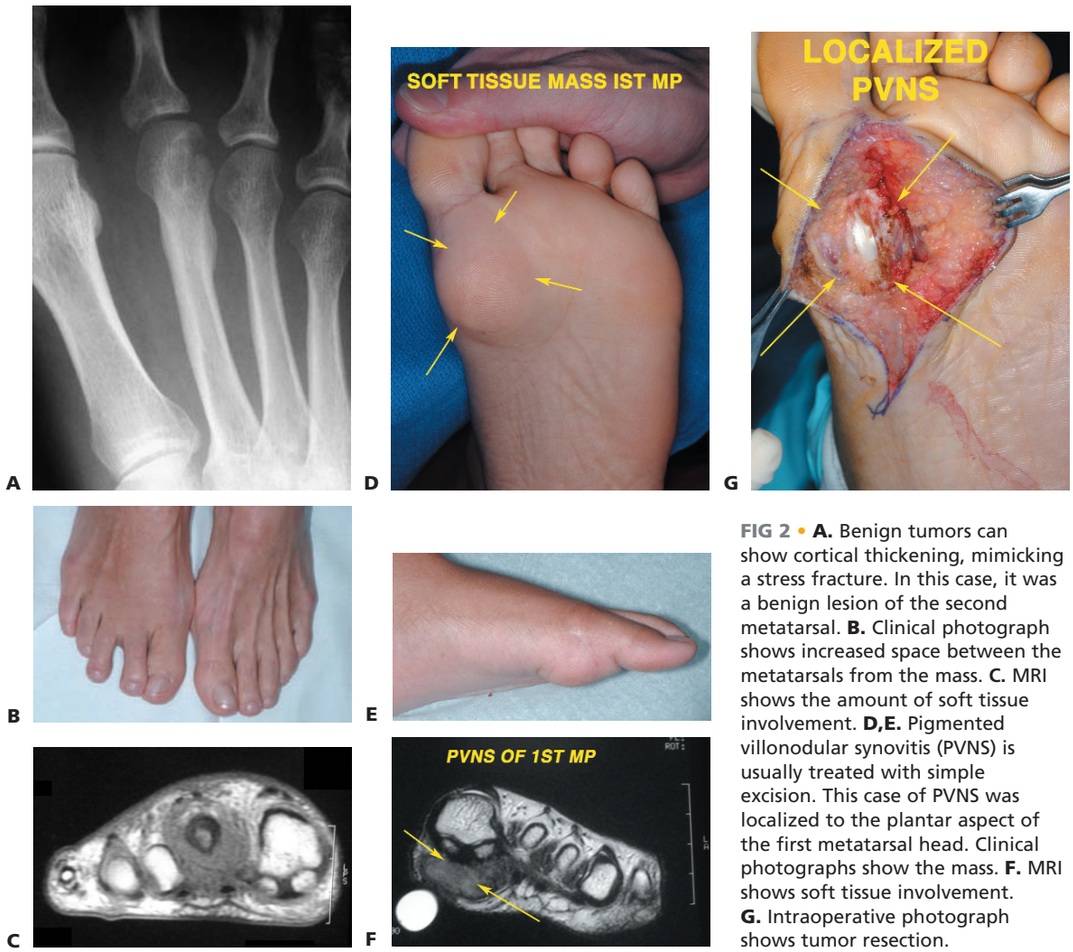


FIG 2 • **A.** Benign tumors can show cortical thickening, mimicking a stress fracture. In this case, it was a benign lesion of the second metatarsal. **B.** Clinical photograph shows increased space between the metatarsals from the mass. **C.** MRI shows the amount of soft tissue involvement. **D,E.** Pigmented villonodular synovitis (PVNS) is usually treated with simple excision. This case of PVNS was localized to the plantar aspect of the first metatarsal head. Clinical photographs show the mass. **F.** MRI shows soft tissue involvement. **G.** Intraoperative photograph shows tumor resection.

Preoperative Planning

- Preoperative planning is crucial for a good outcome. The preoperative radiographs and CT and MRI studies are important to determine the amount of tumor involvement. They also show the extent of soft tissue tumors and may be helpful in distinguishing benign from malignant tumors.[10] The biopsy results will determine the level of amputation.
- The level of amputation is an important part of preoperative planning. The length of the residual stump is as important as the quality of soft tissue. There must be adequate padding of skin, subcutaneous fat, muscle, and tendons to cover the end of the bones.

Positioning

- The patient is placed supine on the operating table. A thigh tourniquet is placed over adequate cotton padding. A bump may be placed proximal to the sciatic notch on the ipsilateral hip to limit external rotation of the extremity during the procedure.

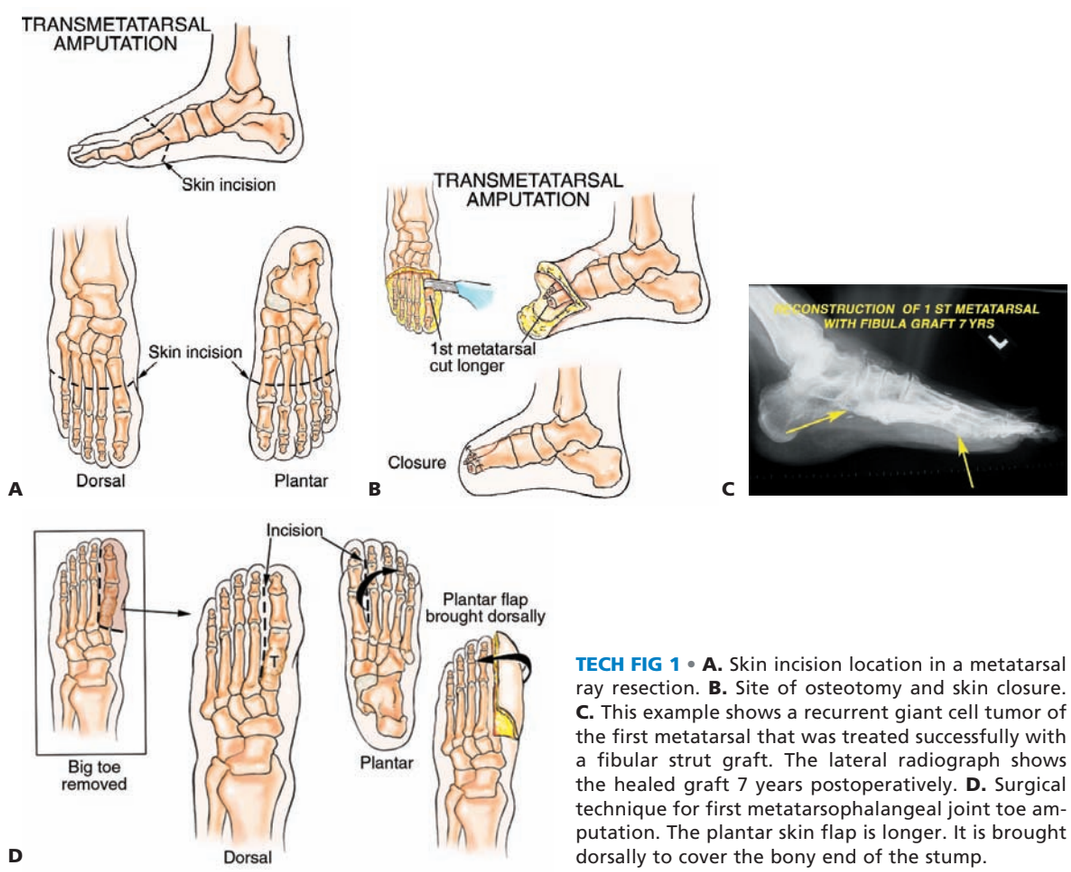
Approach

- The surgical approach is planned preoperatively. It is important to maintain as much plantar skin as possible because this skin is thicker and has specialized columns of plantar fat for weight bearing.

TECHNIQUES

RAY RESECTION

- In performing a ray resection, an incision is made longitudinally and dorsally in line with the involved metatarsal (**TECH FIG 1A,B**). At the metatarsophalangeal joint, the incision is carried plantarly in a curvilinear fashion around the joint. This tissue is then used to reconstruct the resulting web space between the adjacent digits.
- The sensory nerves are identified just beneath the skin and are pulled distally and transected sharply with a scalpel. The extensor tendon is also transected sharply at and proximally near the tarsometatarsal joint.
- The common digital nerve is identified along with the vascular bundle. If they are involved or closely adherent to the tumor pseudocapsule, they are ligated proximally. The lumbrical and interosseous muscles are transected proximally, exposing the base of the metatarsal. It is preferable to preserve the base of the metatarsal if possible because this does not cause any disruption in the arch formed by the tarsal–metatarsal articulation.
- An oscillating saw is used to transect the metatarsal, or the metatarsal is disarticulated at the tarsometatarsal joint and elevated. The resection then is performed from proximal to distal. The flexor tendon is identified and transected. The entire metatarsal is then excised along with the adjacent soft tissue (lumbricals, intrinsics, and flexor extensor tendons). The dissection is then carried distally and plantarward. The capsular structures of the metatarsophalangeal joint are then separated from the underlying dermis, and the ray is removed.
- A suture is placed through the capsular structures of the adjacent metatarsal heads. Pressure is then applied to the tibial and fibular aspect of the foot to close the defect between the adjacent metatarsals, and a 0 nonabsorbable suture is used to anchor the capsular structures between the adjacent metatarsals to bring the metatarsals together and narrow the defect between the adjacent rays. A small drain is placed in the defect and brought out through a separate puncture wound distally. The subcutaneous tissue is then closed with 3-0 absorbable sutures placed in interrupted fashion. The skin is closed with 4-0 nylon sutures placed in interrupted fashion.
- A bulky dressing is applied, maintaining even compression across the foot and compressing the adjacent metatarsals to decrease tension on the capsular stitch maintaining the metatarsal heads in close proximity. If the flexor or extensor tendons are not involved with tumor, they can be woven through the metatarsal heads to create a sling to anchor the metatarsal heads in close proximity and maintain the close space between the metatarsal heads.



TECH FIG 1 • **A.** Skin incision location in a metatarsal ray resection. **B.** Site of osteotomy and skin closure. **C.** This example shows a recurrent giant cell tumor of the first metatarsal that was treated successfully with a fibular strut graft. The lateral radiograph shows the healed graft 7 years postoperatively. **D.** Surgical technique for first metatarsophalangeal joint toe amputation. The plantar skin flap is longer. It is brought dorsally to cover the bony end of the stump.

TECHNIQUES

First Ray Resection with Reconstruction with Autogenous Fibular Graft

- Techniques Figure 1C shows a recurrent giant cell tumor of the first metatarsal that was treated successfully with a fibular strut graft. The lateral radiograph shows the healed graft 7 years postoperatively.
- Under epidural anesthesia an incision is made over the first metatarsal. Anterior and posterior fasciocutaneous flaps are made extending to the level of the second metatarsal anterior and posterior. The proximal limb of the incision extends beyond the metatarsal cuneiform joint, and the distal incision extends beyond the metacarpophalangeal joint.
- Resection consists of the following planes between the first and second metatarsals following the bone in the second metatarsal through the metatarsal cuneiform joint and posteriorly the flexor longus muscle tendon. The distal metatarsal is osteomized at the condyles and proximally just distal to the joint. The tumor mass is removed; the anterior tibial tendon, peroneal tendons, and anterior tibial vessels are preserved.
- Reconstruction is performed with a fibular graft from the midshaft of the fibula of the ipsilateral limb. This is placed within the defect, measuring about 8 cm between the cuneiform and the metatarsal head. Fixation is achieved with two small cortical interfragmentary screws proximally and distally. The hallux is maintained in neutral position.
- Corticocancellous bone graft is placed around the base and the distal osteotomy sites with fibrin glue for hemostasis and to promote healing. The fibular bone graft is taken through a separate incision with separate instruments in the midportion of the fibula on the same side between the peroneus longus and the soleus interval. The muscles are retracted, and the intermuscular septum is released with the cutting electrocautery. An oscillating saw is used to remove 8 to 10 cm of the fibula. The wound is then irrigated, and the peroneal muscles are repaired. A drain is used.

Metatarsophalangeal Joint Amputation

- A longer plantar flap is planned (**TECH FIG 1D**). The incision is carried out at the level of the metatarsophalangeal joint on the dorsum of the foot.
- Sharp dissection is used to expose the joint, and the capsule, ligaments, and tendons are cut at that level. The vessels are cauterized.
- The plantar flap is brought over the dorsal aspect and nylon suture is used to repair the skin.

PEARLS AND PITFALLS

Indications	■ A careful and complete history and physical examination are essential. Preoperative studies are necessary to plan the resection and reconstruction.
Surgical incision	■ A long plantar flap results in a better end-bearing stump. The natural cascade of metatarsal lengths should be maintained.
Wound healing complications	■ Local wound care with dressings and oral antibiotics are usually sufficient for healing.
Deep infection	■ Parenteral antibiotics and surgical débridement may be necessary to treat deep infections. Early diagnosis and treatment can affect outcome.
Contractures	■ Postoperative splinting can help prevent contractures. Once a contracture occurs, it is treated with stretching if mild. Serial casting may be needed.
Painful stump	■ The end of the bones should be contoured to be smooth. A rasp is effective. Adequate soft tissue coverage will help prevent bony prominence, which may become symptomatic.

POSTOPERATIVE CARE

- After a ray resection, the patient is placed in a well-padded splint. Crutches are used until the sutures are removed. The patient may begin range-of-motion exercises and weight bearing as tolerated.
- Toe amputation patients may ambulate in a postoperative shoe immediately. The sutures are removed at 2 to 3 weeks. A wide comfort shoe is worn and activities are progressed as tolerated.

OUTCOMES

- After a toe amputation at the level of the metatarsophalangeal joint, full preoperative function is regained.
- A cosmetic toe prosthesis may be used if the patient desires one, but it has no functional purpose.
- Ray resection outcomes depend on the number of rays amputated and whether the first ray is involved. A ray resection of the second, third, fourth, or fifth metatarsal does not need shoe modification with a molded insert or filler. Generally, ordinary store-bought shoes that are wide and have adequate cushioning are worn.
- A first ray resection affects the remaining foot function because of loss of the windlass mechanism. Reconstruction of the first ray would prevent this problem.
- Removal of two central rays will leave a narrower foot and shoewear problems.

- Patients with a metatarsal ray or transmetatarsal amputation have better outcomes than patients with a Syme amputation.[4]

COMPLICATIONS

- Wound healing complications are treated with local wound care, elevation, and non-weight bearing. Oral antibiotics may be indicated. If there is skin flap necrosis, débridement with a skin graft may be necessary.
- Superficial infection can be treated with a short course of oral antibiotics.
- Deep infection may require immediate operative débridement of devitalized tissue. Parenteral antibiotics are important to treat this limb-threatening problem. At the time of the débridement, a bone culture should be ordered to help determine the appropriate antibiotic.

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