KEY FACTS

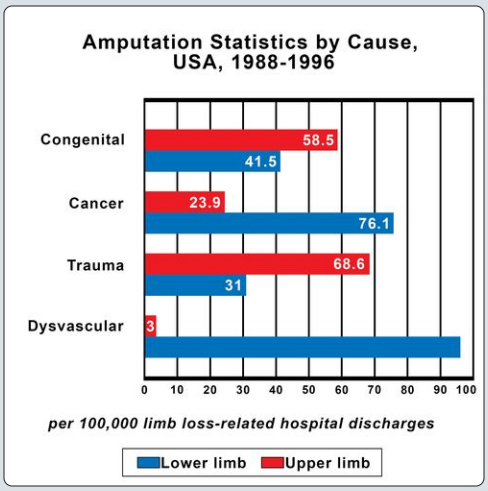
GENERAL

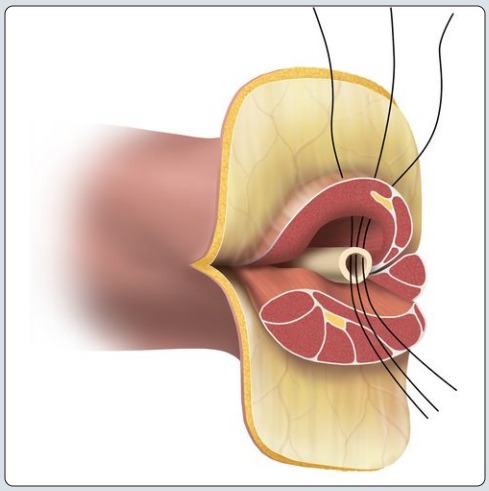
- Amputation and disarticulation should be viewed as reconstructive procedures and not a failure of treatment.
  - In this manner, one realizes that it is the initial step in getting patients back to their previous functional status.
- Indications for amputation include ischemia, trauma, infection, tumor, and painful dysfunction of the foot and ankle not amenable to further conservative management.
- The goal is to create a modified limb that has a comfortable interface with a prosthesis and offers the most efficient energy-conserving gait as possible.
- A team effort, with a team composed of different medical specialists, is the best way to ensure a good result and restore patients to their optimal level of function.
- It is important to be aware of the psychosocial recovery of the patient with an amputation.
- Functional outcome is generally worse in patients with diabetes or end-stage renal disease.

IMPORTANT POINTS FOR SURGICAL APPROACH TO AMPUTATION

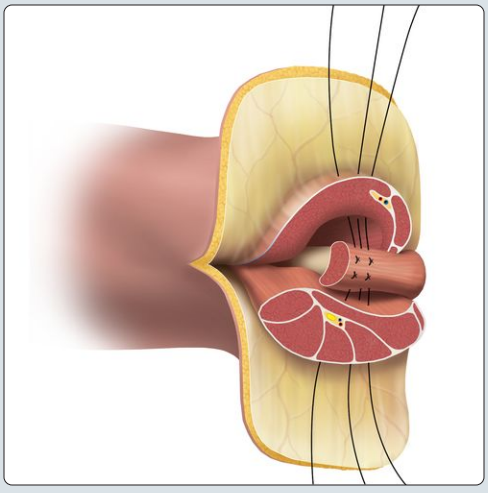
- Team assessment
- Atraumatic soft tissue handling
- Adequate skin flaps
- Myodesis or myoplasty whenever possible
- Nerve transection sharp and at level well above amputation
- Artery and vein dissected free and double ligated
- Closure without tension
- No "dog ear" resection
- Accept delayed primary closure if there is tension

(Left) *USA amputation statistics by cause is shown. [From Adams PF et al. (1999) Current estimates from the National Health Interview Survey, 1996. Vital Health Stat 10: 200.]* **(Right)** *Myodesis consists of suturing the transected muscle to the bone through drill holes.*





(Left) *The cut ends of antagonistic muscle groups and their fascias are sewn together for myoplasty.* **(Right)** *Equivalent-length dorsal and plantar full-thickness fish mouth-type skin flaps should be created, thus favoring the tougher plantar skin for the end of the stump.*



INDICATIONS

Peripheral Vascular Disease

- Peripheral vascular disease (PVD) is the most common reason for amputation.
  - Affects mainly geriatric patients and those with diabetes mellitus.
- Up to 20% of patients with diabetes mellitus will suffer from PVD.
  - Patients are prone to develop foot ulcers leading to lower extremity amputation.
- Peripheral neuropathy increases risk of complications.
  - Loss of protective sensation compromises the likelihood of healing ulcers.
- Prior to considering amputation, vascular studies are useful to determine the following:
  - Possibility of revascularization
  - Level of amputation
- 25% of diabetics who undergo amputation will require an amputation on the contralateral limb within the following 3 years.
- Because of the medical complexity of these patients, optimal management is multidisciplinary with a team composed of a primary care physician, internist, surgeon, physiatrist, physical therapist, prosthetist, and social worker.
  - The input of an infectious diseases specialist may also be required.
- PVD accounts for 90% of amputations with 97% of dysvascular amputations performed on the lower limb.
- African American males are at greatest risk for dysvascular amputation.
  - They are 2-4x more likely to lose a limb than white persons of similar age and gender.
- In amputees with PVD, the 5-year survival rate is between 70-90% with heart disease as the leading cause of death (51%).
  - This is possibly because the coronary heart vessels are subject to the same occlusions as the peripheral arteries.
- Approximately 50% of dysvascular amputees are diabetic.

Civilian Trauma

- Several well-established scoring systems have been developed to help in arriving at a decision to perform an immediate amputation following lower extremity trauma.
- A commonly used scoring system is the Mangled Extremity Severity Score, which consists of 4 categories: Skeletal/soft tissue injury, limb ischemia, shock, and age.
  - A lower number of points indicates a less severe injury.
  - A total score of 7 or below is almost always compatible with limb salvage.
- It is felt by some that soft tissue injury severity has the greatest impact on decision-making regarding limb salvage vs. amputation.
- There are several other proposed limb salvage scoring systems.
- While they may provide guidance for a treating surgeon, none of the scoring systems are considered very reliable in predicting need for amputation.
- In cases of severe limb damage, primary amputation at first surgery may be best for the patient's physical and psychologic well-being.
- In other cases, it may be better to plan an initial attempt at limb salvage and observe.
  - Prolonged attempts at limb salvage lead to severe psychologic and economic burdens on the patient and the family.
- If it is thought that amputation is inevitable, it should be performed as a delayed primary amputation within the first 10-14 days after injury.
- Almost 70% of trauma-related amputations are upper limb amputation.
- The most common causes of lower extremity trauma requiring amputation are lawn mower injuries and motorcycle accidents.
- Traumatic amputees have a better functional prognosis than dysvascular amputees.

Military Trauma

- The changing nature of military conflicts over the past few decades has lead to an increasing number of blast injuries.
  - A mangled extremity is a common combat injury.
- While advances have been made in limb salvage of complex injuries, amputation sometimes offers the best outcome.
- In several studies of wounded soldiers, immediate and delayed lower extremity amputation patients generally have better functional outcomes compared to limb salvage, both physically and psychologically.
  - This is not true for every patient but rather represents a trend for the groups as a whole.
  - Individual decisions are made based on the extent of injury, the experience of the surgeon, and the capabilities of the health care system.
  - Immediate amputation may be necessary for a critically ill patient in a combat zone, whereas the same injury in a stable patient at a tertiary center may be offered limb salvage.

Malignancies

- The most common malignant tumor found in the region of the foot and ankle is synovial sarcoma.
- While metastases to the feet are uncommon, any cancer can metastasize to bone, and any bone can be involved.
- The most common primary tumors that metastasize to the feet are as follows:
  - Carcinoma of lung
  - Adenocarcinoma of colon
  - Genitourinary carcinoma
  - Melanoma
  - Other undifferentiated tumors
- The development of limb salvage procedures, combined with chemotherapy, has reduced the incidence of amputation for primary malignancies of the lower extremity.

Infection

- Life-threatening infection of the lower extremity requires an open amputation.
  - The stump can be closed only when it is certain that the infectious process is under control.
- In some circumstances, repeated debridement and lavage in the operating room is required until the stump is clear of infection and necrotic tissue.

- Chronic osteomyelitis is not an absolute indication for amputation.
  - It can be managed with good preoperative planning and selective surgery, including fistulectomy, sequestrectomy, and similar less invasive procedures.
  - Plastic surgery is often required for coverage of soft tissue defects.
- The ultimate function of the salvaged limb should justify the physical and psychologic costs of the treatment.
- Recurrent infection points to the possibility of PVD.
  - It prevents adequate perfusion of the infected area.
    - Decreased efficacy of antibiotic therapy
- Recurrent infection is common in patients with diminished protective sensation combined with bony deformities leading to abnormal pressure points and recurrent ulcers.
  - Charcot neuroarthropathy involving the foot and ankle is a major cause of recurrent infection.

Dysfunctional Limb

- Painful dysfunction of the limb following several attempts at reconstruction is a rare indication for amputation.
  - A classic example might be a young patient with severe collapse of the talus with avascular necrosis following trauma.
  - If the patient wants to run distances, he or she is more likely to achieve that goal with a transtibial amputation than a pantalar fusion.
- In some cases, consultation with a pain management specialist and a psychiatrist is helpful.
- With the correct indication, a well-healed stump, and a properly fitted prosthesis, many patients with painful dysfunction of the limb will benefit from amputation and regain excellent function with significant pain relief.
- The most common level of amputation for a dysfunctional foot and ankle is a long transtibial amputation, provided that the soft tissues forming the stump are healthy.
- A well-functioning transtibial amputation in a healthy young person will lead to better function than a multiply fused foot and ankle (such as a pantalar fusion).

LEVEL OF AMPUTATION

- Determining the appropriate level of amputation or disarticulation is the most important, and probably the most difficult, part in the treatment of a patient who has no hope for limb preservation.
- If the indication for amputation is a malignant tumor, a life-threatening infection, or an irreparably damaged body part, then the level of amputation must be done proximal to the lesion, in healthy tissues.
- If amputation is performed for PVD, a thorough evaluation of arterial blood flow is essential.
  - Forefoot and toe blood pressure obtained using Doppler devices are of limited value.
    - Artificially high values may be obtained from heavily calcified, hence incompressible, vessels.
- Transcutaneous oxygen measurements (tc*P*o2) can assist in evaluating tissue oxygenation to the dorsal distal metatarsal level.
  - Greater than 30-40 mm Hg indicates wound healing is likely.
  - Less than 20 mm Hg indicates wound healing is unlikely to occur at that level.
- Hyperbaric oxygen chamber therapy with 100% oxygen at 2.5 atm may help wound healing for those patients who are able to increase their tc*P*o2 to 40 mm Hg under the administration of 100% normal baric oxygen via a snugly fitting mask for 20 minutes.
- The presence of palpable pulses does not guarantee healing of the stump.
  - The patient may have heavily calcified arteries or poor peripheral blood distribution due to microangiopathy.
- The presence of hair on the leg or the dorsum of the foot is a positive sign for adequate skin perfusion and secondary wound healing.
- The presence of a thermal gradient from proximal to distal, as well as skin trophic changes, is a clinical sign of poor vascular supply to the soft tissue envelope.
- Lack of protective sensation by itself should not be a factor in considering a more proximal amputation level.
- There is a 2.5x higher complication rate of infection and reamputation in patients who continue to smoke after amputation.
- Platelet function and fibrinogen levels require ~ 1 week of smoking cessation to return to normal levels.
- Perfusion should be optimized by avoidance of vasoconstrictors, such as nicotine and caffeine.
- Serum albumin level below 3.0 g/dL, total lymphocyte count < 1500/mm³, and poor glucose control in patients with diabetes (Hb A1-C > 7% or 8%) significantly decrease wound-healing potential.
- Partial foot amputation is associated with major advantages over higher amputation levels, including:
  - Preservation of weight bearing
  - Improved proprioceptive function
  - Decreased disruption of body image
  - In addition, requires only shoe modifications or limited prosthesis
    - Especially true in older patients or those with diabetes
- A determined effort should be made to save maximum length to enhance function.
  - At the same time, the likelihood of healing should be sufficiently high to avoid the need for repeat surgery.
- In cases of peripheral ischemia secondary to frostbite, vasoconstrictor administration for hypotension, and cryoglobulinemia, it is essential to allow time for completion of tissue demarcation and to keep the necrotic areas dry.
  - In many cases, maximum tissue preservation can be achieved by allowing autoamputation of the necrotic portions.
  - No urgent surgery should be done until the necrotic tissues are well demarcated and the ischemic wounds are dry.
- A contracted knee despite intensive physical therapy is an indication for a knee disarticulation instead of a transtibial amputation.
  - The prosthesis can only partially compensate for the lack of extension of the knee, thus making ambulation challenging.
- A nonambulatory patient requires a level of amputation that will ensure the best chance of healing whenever a lower level might be questionable.

- Split skin grafts should be avoided, especially on surfaces that experience significant shear forces, such as at the end of the stump, where they may ulcerate.
  - In younger children, there will be more remodeling of the soft tissues, and simple skin grafts may be more successful.
- Patients with significant gangrenous changes of the heel pad should have a transtibial amputation.

PHYSIOLOGY OF AMPUTATION: ENERGY EXPENDITURE

- The metabolic demands of walking are increased by the following factors.
  - Decreasing residual limb length
  - Increasing number of amputated joints
  - Increasing number of amputated limbs
  - Dysvascular amputation
- The rates of metabolic energy expenditure ($VO2$, mL/kg per minute) at various amputation levels were compared with those of nonamputees, demonstrating the increased metabolic costs.

SURGICAL TECHNIQUE

- A well-planned amputation or disarticulation conserves all tissue possible according to the diagnosis and good function.
- The skin is the most important tissue for the healing of the amputation wound.
  - It therefore must be handled very carefully with the use of skin hooks.
- The transected muscles should provide an adequate soft tissue mantle for the residual extremity.
- The soft tissue envelope must be mobile, because it will absorb the normal and indirect shear forces during prosthetic usage.
- Myodesis consists of suturing the transected muscle to the bone through drill holes.
- Myoplasty refers to the suturing of the cut ends of the antagonistic muscle groups and their fascias together.
- Bony prominences, such as sharp edges and corners, must be removed and the cut surfaces properly contoured to prevent damage to the soft tissue envelope.
- All transected nerves develop a neuroma, which is painless in the vast majority of patients.
- Neuromas within the weight-bearing area can become painful.
  - Each nerve must be dissected free and sharply transected at a level well above the level of amputation.
- Arteries and veins must be dissected free and doubly ligated before transection.
  - They must be independently ligated in order to prevent the development of an aneurysm or arterial venous fistula.
- Split-thickness grafts may be used occasionally but only over soft tissues and not placed over bone or thick scars.
- Skin grafts are more successful in children than in adults.
- During wound closure, the flaps are trimmed to fit without tension.

SPECIFIC LEVELS OF AMPUTATION AND DISARTICULATION

Toe Amputation or Disarticulation

- Before considering toe amputation, it is essential that the midfoot is sufficiently vascularized to allow for healing of the surgical wound.
  - The tc$Po2$ is measured at the level of the midfoot.
    - Should never be < 20 mm Hg
    - And ideally > 30 mm Hg
- If more than 1 toe requires amputation in a vascular patient, one should consider performing a transmetatarsal amputation.
- Whenever possible, it is advisable to save the proximal phalanx of the 1st ray.
  - This helps with balance, putting on a shoe, and results in a better gait than after disarticulation at the metatarsophalangeal joint with its accompanying loss of the sesamoids and the flexor hallucis complex.
- Equivalent length dorsal and plantar full-thickness fish mouth-type skin flaps should be created, thus favoring the tougher plantar skin for the end of the stump.
- Extensor and flexor tendons should be transected and allowed to retract.
- "Dog ears" should not be resected, as they will retract and assume a smooth contour.

Ray Resection of Foot

- The most common indication for medial ray amputation is septic arthritis or osteomyelitis secondary to a penetrating ulcer under the 1st metatarsal head.
- First ray amputation should be as limited as possible for effective orthotic restoration of the medial arch.
  - In 1st metatarsophalangeal joint septic arthritis with a viable great toe, the joint alone can be removed through a medial longitudinal incision.
- The cut 1st metatarsal should be beveled on its plantar and medial aspects to avoid a high-pressure area and permit appropriate fitting of shoes.
- If the length of the 1st metatarsal is too short due to excessive resection, a planovalgus position of the foot may occur secondary to loss of medial column support.
- Both strength and gait can be seriously impaired because of a too short 1st ray amputation.
- Provided that there is good vascularity on the dorsum of the foot, other single ray amputations are feasible.
- Resection may be carried out through the proximal metaphysis, where the involved ray intersects with the adjacent metatarsals.
- It is not recommended to resect 2 or more central rays.
- If necessary, the 5th metatarsal should be transected obliquely.

Transmetatarsal Amputation

- Transmetatarsal amputation should be considered when:
  - When most or all of 1st metatarsal must be removed
  - If 2 or more medial rays must be amputated
  - If more than 1 central ray must be amputated
- It is the most proximal amputation where patients are able to walk with an almost physiological gait.
  - All the tendons that attach to the midfoot base of the metatarsals are left intact.

- Achilles tendon lengthening or gastrocnemius recession is recommended to further decrease distal plantar pressures.
- The longer the length of the shaft of the metatarsal, the better the function.
- Distal coverage of the metatarsal shafts with a durable plantar flap is of utmost importance.
- To achieve maximum length, the transverse plantar incision is made at the base of the toes.
  - The dorsal incision is made 3-5 mm distal to the metatarsal cuts.
- Metatarsal cuts must be performed in an elliptic manner.
  - Start with the 1st metatarsal and remove as little bone as possible.
  - Lesser metatarsals should be cut roughly perpendicular to the shaft axis.
- Metatarsal shafts should be beveled on the plantar surface to decrease distal plantar pressures.
- Postoperative care includes a well-padded cast with the foot plantigrade or slightly dorsiflexed to prevent equinus.
  - Regular cast changes are needed until the wound is well healed.
  - Change cast to shoe with filler and stiff rocker sole at ~ 6 weeks.
    - When wound is healed

Metatarsal Disarticulation (Lisfranc)

- The indications for amputation at the level of the Lisfranc joint are limited.
  - Trauma and selected cases of foot tumors are the main indications.
- The foot becomes unbalanced because of the loss of forefoot lever and the massive triceps surae overpowering the relatively weaker dorsiflexors.
  - This leads to an equinus contracture.
- Transfer of the distal insertion of the peroneus longus and the tibialis anterior to the medial cuneiform, and leaving a portion of the base of the 5th metatarsal to preserve the insertion of the peroneus brevis tendon, will improve residual foot balance.
- Preservation of the base of the 2nd metatarsal helps maintain the proximal transverse arch.
- Percutaneous Achilles tendon lengthening is recommended to weaken the triceps surae relative to the ankle dorsiflexors.
- Compared with a transmetatarsal amputation, the Lisfranc disarticulation results in a major loss of forefoot length.
  - It correlates with impaired barefoot walking.
- Postoperative care includes a well-padded cast with the foot plantigrade or slightly dorsiflexed to prevent equinus.
  - Regular cast changes are needed until the wound is well healed.
  - Change to shoe with filler and stiff rocker sole at 6 weeks.

Midtarsal Disarticulation (Chopart)

- The disarticulation is performed through the talonavicular and calcaneocuboid joints.
- Even more so than with the Lisfranc disarticulation, the stump has a tendency to develop an equinus posture over time because of severe muscle imbalance between dorsiflexor and plantar flexor muscles.
- The tendency to develop an equinus posture is even greater than with the Lisfranc disarticulation.
  - This occurs due to severe muscle imbalance between dorsiflexor and plantar flexor muscles.
    - Leads to pain &/or ulceration
- The tibialis anterior and long extensor tendons must be inserted into or around the talar neck in order to balance the foot in the sagittal plane.
  - An Achilles tendon lengthening or even complete tenotomy is needed to prevent equinus.
- The main advantage over a more proximal amputation level is that it allows end bearing and does not sacrifice leg length.
- In some cases, it requires only a filler in a regular shoe.
- In the more active patient, however, a formal prosthesis (with a sleeve around the calf) is required because the shoe is unstable.
- Postoperative care should include a well-padded cast in neutral to slight dorsiflexion.
  - At 6 weeks, change to a close-fitting rigid ankle prosthesis/orthosis plus shoe with rigid rocker sole.

Syme Ankle Disarticulation

- Originally described in 1843 by James Syme, it provides an end-bearing stump that allows ambulation without prosthesis over short distances.
  - The heel pad is preserved.
  - It requires a patent posterior tibialis artery.
    - Main source of flow to heel pad
- The limb will be ~ 4-6 cm shorter than the opposite leg.
- Contraindications include the following:
  - Infection or severe traumatic damage to heel pad
  - Inadequate blood flow to heel pad
  - Uncompensated congestive heart failure with pedal and heel edema
  - Psychosis
  - Patient noncompliance
- In the presence of severe foot trauma or infection, a 2-stage amputation is recommended.
  - The wound is initially left open.
  - The viability of the heel flap is established prior to the definitive wound closure.
- Excellent amputation for children, because it preserves the physes at the distal end of the tibia and fibula.
  - About 70% of children with a Syme amputation will participate in sports.
- This level of disarticulation is more energy efficient than a transtibial level.
  - About 70% of adults will be able to return to work.
- The presence of an insensate heel is not a contraindication to a Syme ankle disarticulation.
- Take care to preserve the posterior tibial neurovascular bundle and the integrity of the fat-filled fibrous chambers of the heel pad.
- Iatrogenic disruption of the heel pad during dissection will lead to heel pad atrophy and a dysfunctional weight-bearing stump over time.
  - Heel pad provides shock absorption on heel strike.
  - Bruising of the posterior tibial vessels may lead to thrombosis and loss of the heel pad.

- Before closure, the interior of the heel pad must be carefully palpated for flakes of residual cortical bone.
  - It must be removed to avoid painful bony growth.
- At closure, the heel pad flap must be perfectly centered under the leg and secured to the anterior tibial cortex by suturing the plantar fascia through drill holes.
- Never trim the redundant tissue ("dog ears").
  - It provides vascularity to the distal part of the flap.
- Patients will need a below-knee prosthesis.
  - This can be a molded plastic socket with a removable medial window through which the stump is inserted or a similar type of prosthesis, to which a foot unit is attached.
- Removal of the calcaneus from the heel pad creates a large empty space, and a drain should be inserted to prevent the formation of a large hematoma.
  - It is removed 2 days postoperatively.
- Postoperative care should include a carefully molded cast placing the heel pad in a slightly forward and centered position.
  - Weekly cast changes are performed until the wound is well healed at ~ 4-5 weeks.
  - A temporary prosthesis is then fitted with a walking heel cast, which is changed every 2 weeks (or whenever loose).
  - Final prosthetic application is performed once the limb volume has stabilized.
- There is an alternative to a Syme level for the rare patient with just a bit more soft tissue: Pirogoff procedure.
  - In the Pirogoff procedure, the talus is removed.
  - The anterior process of the calcaneus is transected and removed as well.
  - The distal tibia is cut flat to expose cancellous bone with minimal bone resection.
  - The calcaneal tuberosity is fused to the distal tibia.
    - Preserves more length than Syme procedure but requires ~ 6 weeks of non-weight bearing for fusion

Transtibial Amputation

- As compared with more distal levels of amputation, the following holds true:
  - End weight bearing is no longer possible.
  - Walking will not be feasible without a prosthesis.
- In comparison with a higher level of amputation, the knee joint is preserved.
  - This facilitates ambulation, balance, and walking pace changes.
  - It also decreases the energy expenditure involved in ambulation.
- The ideal length of the bone stump is between 12-17 cm below the joint line of the knee.
  - Shorter stumps up to the insertion of the patellar tendon may still present some benefit to the patient.
- It is the quality of the soft tissue envelope that will determine the length of the stump.
- Careful inspection and clinical evaluation, including tc*P*o2 measurements, are required.
- Biomechanically, a longer stump provides a better lever arm and hence improved function.
  - However, there is less soft tissue distally to adequately cover the bony stump.
  - This can lead to pressure sores, chronic ulceration, and challenging prosthetic fitting.
  - Some residual length is necessary to accommodate the pylon and the foot/ankle prosthetic unit.
- Approximately 90% of transtibial amputees successfully use a prosthesis, compared with a rate of < 25% of geriatric dysvascular transfemoral amputation patients.
- The shortest useful transtibial amputation must include the tibial tubercle to preserve knee extension.
- In a very short transtibial amputation, the fibular head and neck should be removed and the common peroneal nerve transected high above the knee.
  - Knee flexion during this maneuver may help achieve a higher transection of the nerve.
- Flap configuration is determined by the soft tissue envelope.
  - Equal anterior-posterior, medial-lateral, or long posterior flaps may all be good options as long as they allow myodesis to the tibia to prevent adherence of skin to bone and to provide good padding.
- Amputation with a long posterior flap, as popularized by Burgess (1971), is most desirable in patients with vascular disease.
  - It leaves the patient with a scar on the anterior aspect of the residual limb.
  - Due to the thick myofasciocutaneous flap, there is very little risk of soft tissue problem at the end of the stump.
- The anterior distal aspect of the tibia must be carefully beveled, removing a significant portion of bone.
- The fibula must be transected 1.5 cm proximal to the level of the tibial transection.
- A knee contracture > 15° that does not respond to intensive physical therapy in a patient with limited ambulatory function is a contraindication to transtibial amputation.
- Postoperative care should include a carefully molded cast extending proximally to the mid- or upper thigh in extension to avoid hamstring contractures.
  - A good supracondylar mold to prevent cast slippage is helpful.
    - Or waist band and suspension strap may be used.
  - After 5-7 days, the cast may be changed to a prosthetic cast if wounds are healed.
  - Serial prosthetic casts should be placed every 7-10 days, or whenever loose, until stump maturity (6-8 weeks).
  - At this time, the transition can be made to a preparatory or definitive prosthesis (requiring fitting).

Knee Disarticulation

- Knee disarticulation allows for end weight bearing through the end of the stump (in a prosthesis).
- Compared with a transfemoral amputation, it maintains a long active lever arm for control of the prosthesis with excellent muscle attachments.
  - The bulbous distal stump enhances suspension (of the prosthesis).
- The prosthesis is end bearing, which avoids the need for the ischial pressure and suspension belts that transfemoral amputation requires.
- In the nonambulatory patient, it provides better balance for wheelchair activities and prevents hip flexion contractures, as compared with transfemoral amputation.

- The skin incisions are not much more proximal than those of a short transtibial amputation.
  - Therefore, before deciding to perform a knee disarticulation, one must be sure that a short transtibial amputation is not indicated.
- Prosthesis tolerance, compliance, and comfort are significantly higher than in those patients with a transfemoral amputation.
- In the past, there have been some concerns with regard to the difference in height of the knee joints between the sound limb and the disarticulated limb.
  - However, with recent prosthetic technologies, this is not an issue sufficient to deny its numerous advantages over a transfemoral amputation.
- The cruciate ligaments are detached from the tibia and retained for suturing to the patellar tendon without pulling the patella over the end of the femur.
- Bone excision is not required, nor is it necessary to remove articular cartilage.
- Medial and lateral sagittal flaps, with an incision extending from distal to posterior, allow the final suture line to stay posterior between the femoral condyles.
  - This eliminates a surgical scar at the end of the stump in the weight-bearing area.
- A method of closure with use of the posterior calf skin and gastrocnemius muscle bellies, as an integral flap has been described with good results.
- Postoperatively, a soft dressing or rigid cast should be applied depending on weight-bearing goals.
  - Casts should be molded in a similar fashion to those in transtibial amputation in order to avoid slippage.
    - Often require suspension belt
  - Once wounds are fully healed, transition to a prosthesis for weight bearing can begin.
    - Serial fittings in 7- to 10-day increments until stump maturity

Transfemoral Amputation

- Transfemoral amputation is associated with a high degree of disability.
- Prosthetic compliance is low in the geriatric population.
  - Most elderly patients do not wear their prosthesis and will remain in a wheelchair.
- Energy expenditure is high and makes ambulation difficult in patients with associated comorbidities, such as cardiopulmonary illnesses.
- Body image is negatively affected to the degree that some patients may become severely depressed.
- In particular, patients undergoing transfemoral amputation will greatly benefit from a multidisciplinary team approach aiming at improving their physical, psychologic, and social outcome.
- Healing is generally very good due to the large amount of soft tissue and rich vascular perfusion in the thigh, even in patients with vascular disease.
- Transfemoral amputation has been the most commonly used amputation level for vascular disease, because of its reliable healing rate.
  - This should no longer be the case in developed countries.
  - Patients may benefit from peripheral vascular surgery and objective assessment of skin perfusion through multilevel measurements.
- The technique of transfemoral amputation has evolved over the past decade.
  - Maintenance of the femoral shaft axis close to normal can be achieved by preservation of the adductor magnus and by myodesis of the muscle to the residual femur.
- The 2nd most common complication (after phantom limb pain) is a flexion and abduction contracture of the hip.
  - This will interfere with ambulation and prosthetic fitting.
  - Good surgical technique using myodesis of the adductors and myoplasty of hamstrings to quadriceps, as well as early postoperative physical therapy, will minimize this complication.
- Postoperative care is similar to that of knee disarticulation.

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Scoring Systems for Severely Injured Limbs

Reference	Name of Score	Acronym
Gregory et al (1985)	Mangled Severity Extremity Index	MESI
Howe et al (1987)	Predictive Salvage Index	PSI
Helfet et al (1990)	Mangled Extremity Severity Score	MESS
Russell et al (1991)	Limb Salvage Index	LSI
McNamara et al (1994)	Nerve, Ischemia, Soft tissue, Skeletal, Shock, Age Index	NISSSA

Mangled Extremity Severity Score Variables

Variable Group	Description	Points
Skeletal/Soft Tissue Injury		
	Low energy (stab, simple fracture)	1
	Medium energy (open fracture, multiple fractures)	2
	High energy (high-velocity gunshot, crush)	3
	Very high energy (above + gross contamination)	4
Limb Ischemia		
	Pulse ↓ or absent, perfusion normal	1
	Pulseless, paresthesias, ↓ capillary refill	2
	Cool, paralyzed, insensate	3
Shock		
	Systolic blood pressure always > 90 mm Hg	0
	Transient hypotension	1
	Persistent hypotension	2
Age		
	< 30 years	0
	30-50 years	1
	> 50 years	2

Score of 7 or less is nearly always compatible with limb salvage. Ischemia score is doubled for ischemia > 6 h.

Effect of Different Amputation Levels

Level of Amputation	Body Image Disruption	Leg Length Preservation	Preservation of End Weight Bearing	Proprioceptive Function	Ability to Walk Without Prosthesis	Limited Prosthesis	Full Prosthesis	Walking Pace Adaptation
Transmetatarsal	±	Y	Y	Y	Y	Y	N	Y
Lisfranc-Chopart	±	Y	Y	Y	Y	Y/N	Y/N	Y
Ankle (Syme)	+	N	Y	N	Y	N	Y	Y
Transtibial	+	N	N	N	N	N	Y	Y
Knee disarticulation	++	N	Y	N	N	N	Y	N
Transfemoral	+++	N	N	N	N	N	Y	N

Increased Metabolic Costs At Various Amputation Levels

Amputation Level	Increase in Metabolic Cost (%)
Syme	15
Traumatic transtibial	25
Traumatic transfemoral	68
Vascular transtibial	40
Vascular transfemoral	100

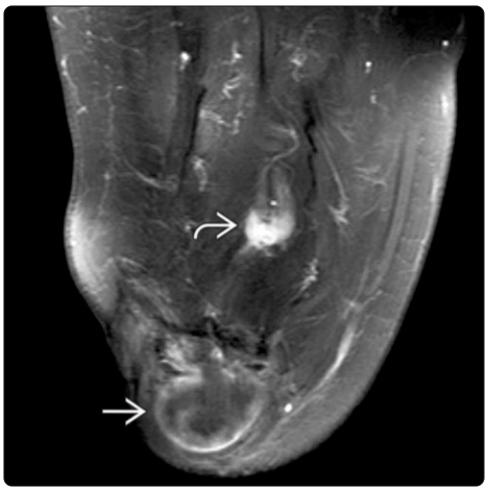
(Left) *Transmetatarsal amputation is shown. Distal coverage of the metatarsal shafts with a durable plantar flap is of utmost importance.* **(Right)** *Transmetatarsal amputation is shown. The metatarsal cuts must be performed in an elliptic manner, starting with the 1st metatarsal. Metatarsal length depends on the status of the plantar flap. Ideally, metatarsal length should be as long as possible to give the longest lever arm.*

(Left) *AP radiograph shows a Chopart amputation, which is a disarticulation at the calcaneocuboid and talonavicular joints. Note the tunnel ⇨ placed for anterior tibial tendon transfer. (From DI: MSK Trauma.)* **(Right)** *Lateral radiograph in the same patient shows the talar tunnel ⇨. Despite the tendon transfer, the foot is in equinus, a major challenge with this amputation. The equinus deformity leads to poor biomechanics and predisposes to ulcers and osteomyelitis. (From DI: MSK Trauma.)*

(Left) *The Syme ankle disarticulation (7 days postoperative) provides an end-bearing stump that allows ambulation without a prosthesis over short distances.* **(Right)** *AP radiograph of a Syme amputation is shown. Medial malleolus has been resected. The thick soft tissue flap allows ambulation without a prosthesis. The ends of the stumps are corticated. (From DI: MSK Trauma.)*

(Left) *Amputation with a long posterior flap is most desirable in patients with vascular disease. It leaves the patient with a scar on the anterior aspect of the residual limb, and due to the thick myofasciocutaneous flap, there is little risk of soft tissue problems at the end of the stump.* **(Right)** *AP and lateral radiographs show transtibial amputation. The anterior distal aspect of the tibia must be carefully beveled, removing a significant portion of bone. The fibula must be transected 1.5 cm proximal to the level of the tibial transection.*

(Left) *Knee disarticulation is shown.* **(Right)** *Knee disarticulation with posterior suture line is shown. Medial and lateral sagittal flaps, with an incision extending from distal to posterior, allow the final suture line to stay posterior between the femoral condyles. This eliminates a surgical scar at the end of the stump in the weight-bearing area.*



(Left) *Coronal STIR MR of a patient with an above-the-knee amputation shows fusiform enlargement and increased signal intensity of the transected sciatic nerve characteristic of stump neuroma. A reactive bursa has formed at the distal margin of the stump. (From DI: MSK Trauma.)* **(Right)** *Coronal T1WI Gd FS MR in the same patient shows uniform enhancement of stump neuroma. Bursa, in contrast, shows rim enhancement. (From DI: MSK Trauma.)*

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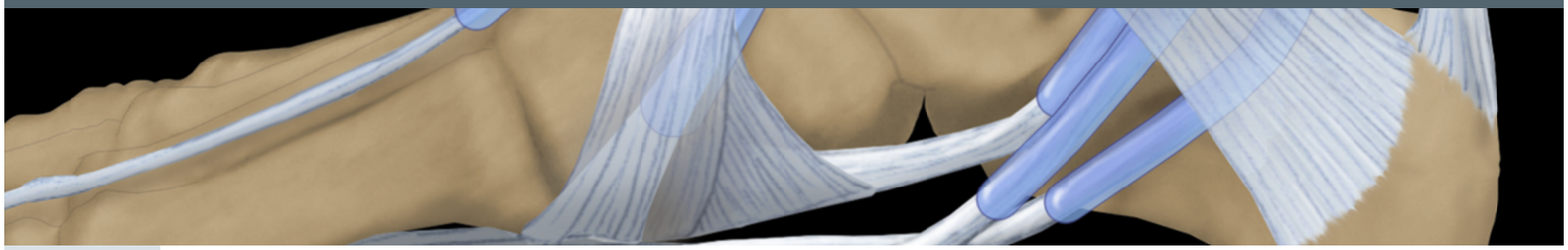

Part I: Core Knowledge in Orthopaedics: Foot and Ankle