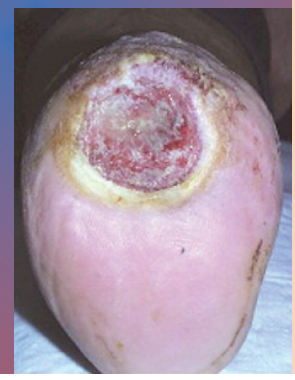
Continuing Medical Education

Save a Limb… Save a Life

Here's a look at the art and science of limb salvage.

BY KENNETH B. REHM, DPM



Objectives

1) To frame the concept of limb preservation and salvage.

2) To appreciate the advantages and disadvantages of amputation of a limb.

3) To understand the advantages and disadvantages of amputation of just part or all of the foot.

4) To describe the different indications for an amputation of a limb versus amputation of all or part of a foot.

5) To motivate and educate the healthcare professional as to the importance of amputating a limb as far distal as what could heal.

6) To define the parameters of the decision-making process of amputating a limb vs. all or part of the foot.

7) To empower the podiatric physician to consider the whole patient when making a recommendation for any amputation.

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General Considerations

The art and science of major limb preservation and salvage, that is, saving a person from a major amputation such as a below- or an above-the-knee amputation, and preserving the whole or a functional part of the foot, must include a commitment to take into account the totality of the patient's life, including the social, financial, psychological and medical co-morbidities. Also necessary is the willingness to use a creative and biomechanically sound focus when considering lesser amputations, such as toe, metatarsal, ray, transmetatarsal, Lisfranc, Chopart or Syme procedures (Figure 10). Even though the advantages of the lesser amputations are well cited in the literature,[3] many surgeons do not view these lesser amputations as viable options for limb salvage.

The literature is scant and therefore more literature needs to be accumulated regarding these limb preservation and salvage issues.[1]

Because of such a high rate of perceived failure of these lesser amputations, as well as the fear of having to re-operate and therefore readmit the patient to the hospital, a surgeon is more likely to perform a

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major amputation on a person who has severe infection, cellulitis, osteomyelitis, or gangrene of the distal half of the foot, even if the procedure might have been successful given the appropriate vascular, radiographic, and medical pre-operative workup. With the recent changes in our healthcare systems, sometimes the definitive work-up may not be done because of risk/benefit, financial, insurance, and hospital issues. The literature is scant and therefore more literature needs to be accumulated regarding these limb preservation and salvage issues.[1]

Figure 1: These images demonstrate a transmetatarsal amputation through all five digits. The bone edges are beveled and there is a generous soft tissue pad.

There are, however, definite indications for major lower extremity amputations. In these cases, amputation is a life-saving event and these patients are obviously and certainly better off after the amputation. In a significant number of these, if the effort is put forth, patients can resume an active, healthy and happy lifestyle. However, when compared to a lesser amputation, the challenges are many and every effort should be made to prevent a major amputation.

A major limb amputation is fraught with inherent potential adverse effects. Overall, these patients have a decreased quality of life as well as increased mortality rates. These individuals often have long treatment periods that can be both painful and time-consuming with much time and resources spent on recuperative and rehabilitative care. Many challenges are present such as needing assistance with activities of daily life, not to mention the psychological problems that need to be dealt with.

Data from several studies[4] indicate that 9%-20% of diabetic individuals experienced a higher or second leg (contralateral) amputation during a separate hospitalization within 12 months after an amputation.

It is commonly contended that preserving limb length should be the primary surgical objective to maintain optimum function and gait;[1] and because energy expenditure is increased with more proximal amputations, there may be devastating consequences on the cardiovascular health of the patient.

Figure 2: LisFranc Amputation: Amputation proximal to the transmetatarsal level

Amputation Study Results

Data from several studies[4] indicate that 9%-20% of diabetic individuals experienced a higher or second leg (contralateral) amputation during a separate hospitalization within 12 months after an amputation. Five years following an initial amputation, 28%-51% of diabetic amputees had undergone a second leg amputation. Peri-operative mortality among diabetic amputees averaged 5.8% in 1989-92, according to the National Hospital Dis-

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charge Survey data. These studies showed the five-year mortality rate following amputation was 39%-68%. The evidence is clear, then, that saving a limb is more than an important adjunct in increasing quality of life and allowing the patient to ambulate.

Despite the shortcomings of major lower extremity amputations, lesser foot amputations are performed less frequently than major amputations.[2]

Limb preservation and salvage are eliminating a major risk factor for further disease and death.

Despite the shortcomings of major lower extremity amputations, lesser foot amputations are performed less frequently than major amputations.[2] In fact, this author performed an informal survey of twenty surgeons who routinely make decisions as to the level of amputations to be considered in patients who have necrotizing fasciitis, osteomyelitis or gangrene. When queried about the level of amputation recommended, if the pathology involved was more than just a toe and was restricted to the distal forefoot: only three stated they would consider a partial or proximal foot amputation. This was conditional upon only the toes being involved and there was adequate circulation and enough skin to appropriately do a plantar flap.

Sixteen surgeons stated that they would recommend a below-the-knee amputation without considering a lesser amputation (which probably would have been successful had the appropriate indicators for healing been evaluated). None of these 16 respondents said that they would perform any sophisticated diagnostics that would assist in determining exactly what level on the foot contained adequate perfusion and viable non-infected tissue for the purpose of knowing how far distal an amputation could be performed that would heal.

Diagnostic Tests

Such tests would include angiography, laser Doppler, transcutaneous oxygen measurements, MRI with a comparison of T1 and T2 weighted images, or indium 111 WBC scans with a sulfur colloid bone marrow scan or a SPECT-CT. Among the reasons given for such aggressive recommendations were that diabetics just don't heal; and that once any amputation is performed, there was a perceived likelihood of failure. This would necessitate further proximal amputations eventually emanating in an amputation of the leg anyway. In addition, these surgeons just assumed, the below-the-knee amputation would heal and thus did not recommend any vascular studies to determine the level of leg amputation.

Only one respondent opted to carefully study all the determinants in order to determine the most proximal amputation that could be performed successfully.

Determinants of a Successful Amputation

After a determination is made that a lesser amputation is in the patient's best interest, determinants that are critical to the success of a lesser amputation must be assessed. Important factors in assuring this success include the evaluation of the actual extent of the cellulitis or infection. Also

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Figure 3: Chopart Amputation: Disarticulation between the calcaneal-cuboid and the talo-navicular joints

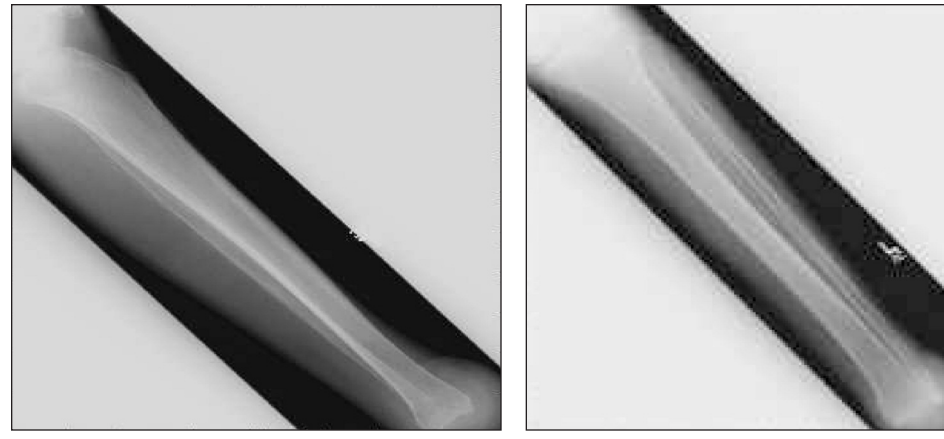

Figure 4 & 5: Syme Amputation: Disarticulation at the ankle

critical is the patient's overall medical and nutritional condition as well as consideration of the exact level of circulation compromise, and differentiating between Charcot deformity and frank osteomyelitis.

Knowledge of skin closure, grafting, skin replacement materials and other factors, such as the potentiality of using skin flaps, are essential to the success of lesser amputations. Other considerations are the biomechanics of post-operative gait, proper physical therapy, gait and strength training, the availability and use of appropriate shoes, inserts, orthotic and prosthetic devices post-operatively. Therefore, given essential vascular perfusion, ability to incise and drain, or debride the infected, necrotic and gangrenous tissue and leave enough tissue to close, in addition to having an opportunity for primary or secondary skin closure and to plan for optimal and balanced gait, maximize the chances of success of the most distal amputation possible.

Defining Lesser Foot Amputations and their Indications

In addition to the common indications to amputation (e.g., infection, peripheral arterial disease with gangrene, etc.), specific indications for toe amputations exist as well. For example, it is not uncommon to remove a deformed or ulcerated lesser toe for imposing a risk factor for cellulitis, osteomyelitis, gangrene or any factor that may predispose a diabetic patient to further amputation. Many surgeons state that a toe can be amputated with impunity and this is usually preferred over reconstructive procedures because it is easy and definitive.

Given that the basic criteria are met, complications of toe amputations with regard to gait are minimal. For example, any single toe can be removed with little or no gait, stance, or balance disturbance. However, possible complications specific to the toes include migration of adjacent toes, particularly when the lateral toes are amputated (Figure 13) or when the first toe is removed. The development of hallux abducto valgus deformity is sometimes seen as a consequence of the removal of the second toe (Figure 8). This is a common complication of second toe amputations and occurs because the great toe tends to drift toward the third to fill the gap left by the amputation.

Many surgeons state that a toe can be amputated with impunity and this is usually preferred over reconstructive procedures because it is easy and definitive.

A common scenario status post-partial or total great toe amputation is the development of a bursa over a hypertrophied 1st metatarsal head, ulceration, or even residual osteomyelitis stemming from the original bone infection. If the metatarsal head is amputated with the toe (Figure 12) and the patient is fitted with a biomechanically appropriate orthosis and shoe, then the chances for post-operative complications are significantly reduced.

Border Ray Amputations

Border ray amputations do not significantly interfere with ambulation. In fact, amputation of the lateral two or even three rays often provides a functional weight-bearing foot. Amputation of the medial two and even three rays in special circumstances

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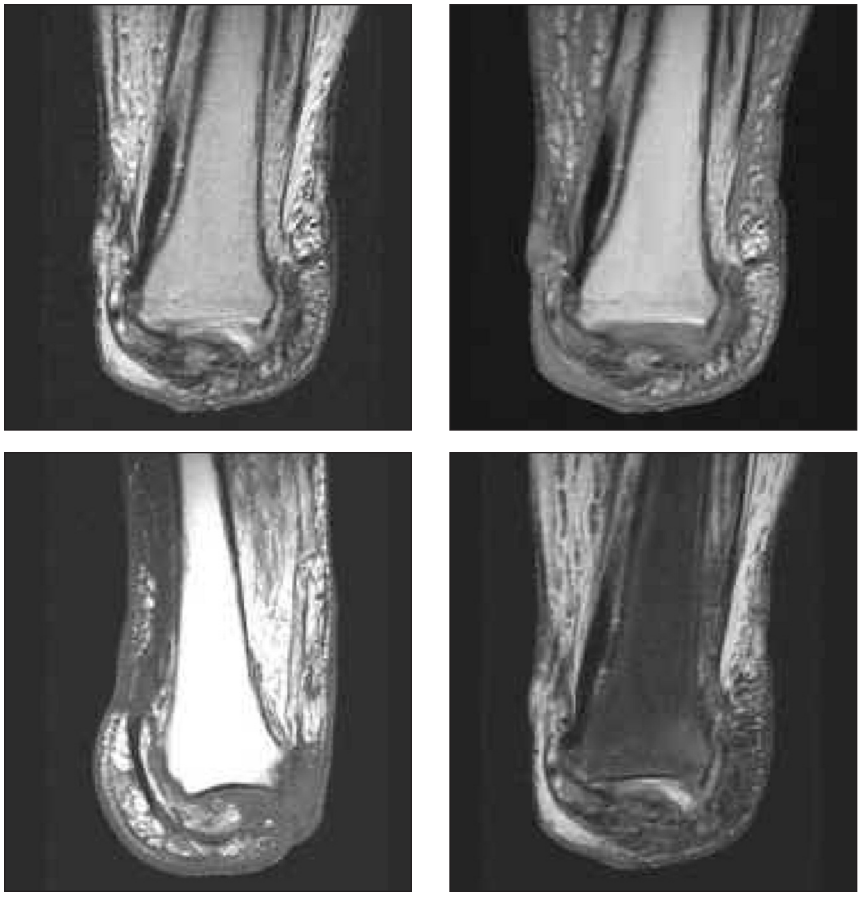

Figure 6: These MRI images below demonstrate the Syme amputation. Note the tissue from the heel forming a pad at the distal stump. This is the principle advantage of this procedure due to the more effective weight bearing.

may provide for adequate weight bearing and a reasonably functional foot. Occasionally because of infection with or without ischemia, particularly in the diabetic foot and occasionally following trauma, removal of one or more of the central rays, either partially or completely, is indicated (Figure 7). It is important to note that even though some degree of weight bearing and functionality on the surgical foot is maintained, the use of appropriate foot wear is essential in optimizing weight bearing and maintaining the integrity of the surgerized foot. Biomechanical principles must always need to be obeyed to avoid complications such as transfer lesions and new ulcerations.

The Transmetatarsal Amputation

The transmetatarsal amputation (TMA) is the removal of the distal foot at the proximal diaphysial junctions (Figure 1). It should be considered when necrosis has damaged the forefoot, there is distal gangrene, osteomyelitis, or when control of infection requires removal of two or more medial rays. The ability to close the wound through primary closure or various plastic surgical procedures or skin flaps is a fundamental consideration. Also, creating a smooth metatarsal parabola for optimal closure and to allow for minimal bony pressure will optimize the success of this procedure.

This amputation can cause more disability than simple toe amputations. The impairment of gait is due to the loss of push-off in the absence of a positive fulcrum in the ball of the foot. The more proximal the amputation, the more disability is likely to be present. In addition, because of the reactive shortening of the posterior muscle groups after this procedure and the resultant plantarflexed position of the post-operative foot, it is standard protocol to consider a tendo-Achilles lengthening procedure for this and any other mid- or proximal foot amputation. However, as with toe amputations, there is no need for a prosthesis other than shoe filler.

The Lisfranc Amputation

The Lisfranc amputation (Figure 2) or the disarticulation at the junction of the tarsus and metatarsus can be used for selective cases of foot infection, gangrene or trauma. Amputations proximal to the transmetatarsal level often result in considerable gait problems. This is secondary to the loss of plantar soft tissue and bony support as well as the inability to properly push-off during the stance phase of gait.

Careful pre-operative evaluation of the level of infection, viable tissue and adequate perfusion allow for a relative high accuracy in predicting which patients will heal. The principle complication of the Lisfranc amputation, as in the TMA, is an equinus deformity due to the loss of dorsiflexory attachments and the overpowering of the dorsiflexion function as a result of the contractural deformity of the foot flexors such as the gastrocnemius and soleus muscle and tendon complex. If severe, such a deformity may contribute to a repeat amputation at a higher level and therefore, just as in the TMA, a tendo-Achilles lengthening should be considered.

Extreme caution should be exercised in using this procedure as failure could compromise the success of a Chopart or Syme amputation.

The midtarsal or Chopart amputation (Figure 3) is a disarticulation through the talonavicular and calcaneocuboid joints, leaving only the calcaneous and talus (Figure 14). It is often used as a surgical prelude to the more definitive Syme amputation when infection might hinder optimum results.

Careful pre-operative evaluation of the level of infection, viable tissue and adequate perfusion allow for a relative high accuracy in predicting which patients will heal.

The Chopart is also prone to an equinus deformity but is usually more severe than with the Lisfranc amputation. In response to this, additional operative procedures have been devised (Roach and McForlane) in order to prevent the early equinus deformity from becoming fixed.

Chopart Amputuation

Like the Lisfranc amputation, the Chopart amputation is a midfoot-level procedure and is responsible for the same gait disturbances. The Chopart is also prone to an equinus deformity but is usually more severe than with the Lisfranc amputation. In response to this, additional operative procedures have been devised (Roach and McForlane) in order to prevent the early equinus deformity from becoming fixed.

Heel cord tenotomies are able to prevent this problem, resulting in only 1 of 44 patients who go on to fixed equinus deformity, according to one of Roach's studies.[5] This is a significant improvement over what was the case prior to such procedures, and may be responsible, in part, for a modest resurgence in the Lisfranc and Chopart procedures.

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It is important to note that when someone has undergone any forefoot amputation, such as those described above, one must expect some degree of disability and rarely, if ever, does gait and functionality regain normality.

Ankle Syme Amputation

The ankle Syme amputation is classically described as amputation of the foot at the ankle joint with retention of the plantar heel that is re-approximated anteriorly. James Syme originally described the amputation in 1843 after having performed the operation on a 16-year-old boy with a chronic foot infection. Its main purpose was to provide a more durable end-bearing stump than more proximal amputations. In his original article describing the procedure, James Syme expresses regret over the number of limbs he had previously amputated that could have been saved with an alternative procedure.

The procedure has met with varied success and acceptance, and several modifications to the classic technique have been introduced with a relatively high degree of success. The level of the amputation is generally at the distal tibia and fibula 0.6cm proximal to the periphery of the ankle joint and passing through the dome of the ankle centrally. Pirogoff (1854) described division through the calcaneous to allow a longer weight-bearing stump. A more successful modification was described by Mazet (1968) and more recently by Sarmiento (1972) which reduced the mediolateral diameter of the stump by trimming the malleoli, thereby decreasing the bulk to facilitate the fitting of the prosthesis and improving the cosmetic appearance.

In the right hands, the Syme amputation can be one of the best amputations of the lower extremity, as it creates an excellent end-bearing stump and allows for a functionally satisfactory prosthesis. If the procedure fails either because of improper technique, or otherwise, a below-the-knee or above-the-knee amputation would be considered, but in reality nothing is lost because, in all probability, a higher amputation would have been performed if the Syme procedure was not. Possible complications of this procedure include posterior migration of the heel pad, skin slough, and a distal flair that leads to a bulky and thus non-cosmetically pleasing result necessitating a prosthesis which is considered to be aesthetically unacceptable.

The Syme amputation is used when preventing a BK or AK amputation and thereby preserving some degree of weight-bearing or transfer ability.

The Syme amputation is used when preventing a BK or AK amputation and thereby preserving some degree of weight-bearing or transfer ability. There is usually significant vascular compromise in the involved limb. However, newer techniques for determination of tissue perfusion such as Doppler ultrasound measurement of segmental blood pressures, radioactive xenon clearance tests, and transcutaneous oxygen or Laser Doppler measurements, combined with newer procedures for vascular intervention and the increased availability of hyperbaric centers have significantly increased the potential for success of the Syme amputation in dysvascular limbs.

Because the lines of indication are blurred between a transtibial and a disarticulation at the ankle, and because the Syme amputation is the most under-utilized and infrequent of all the lesser amputations, this may be where the greatest opportunity for major amputation prevention exists.

Pre-operative Considerations

What is found to be very common practice by this author is that once there is any gangrene or osteomyelitis on a diabetic patient, if the circulation appears diminished in any way, the patient is presumed to be compromised and a major amputation of the limb is performed without seeking evidence to justify a minor amputation. The decision-making process should be a result of gathering evidence of the potential to rid the body of infection and heal the wound. It should involve an extensive medical, nutritional, and vascular workup as well, and evaluation of the patient's psychological and social situation. This protocol should be consistently applied to each patient.

During a recent trip to Milan, Italy, this author was fortunate to have visited Dr. Giacomo Clerici, M.D., a world renowned researcher and clinician who is the director of the Diabetology Section, Centre for the Prevention and Treatment of the Diabetic foot at the MultiMedica Center in Milan. This is a world-class center of excellence for the treatment of the diabetic foot where its medical team is instrumental, creative and aggressive in developing limb salvage techniques.

Dr. Clerici states that his primary concern is being able to perform as distal an amputation as is possible to heal and remain healed with appropriate skin care, biomechanics, post-operative prosthesis, orthoses and shoes.

In a recent interview with Dr. Clerici, he states that his primary

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Figure 7: removal of one of the central rays.

concern is being able to perform as distal an amputation as is possible to heal and remain healed with appropriate skin care, biomechanics, post-operative prosthesis, orthoses and shoes. In complicated situations where skin coverage would be inadequate or where the skin is compromised, it is not uncommon for Dr. Clerici's team to perform skin flaps from as distant as the shoulder or back in order to assure the success of a Syme or Chopart's amputation. He states that if he is true to his selection criteria, out of every 100 Chopart's amputation, maybe 10-12%, go on for more proximal amputations.

Figure 8: Second toe amputation with resultant hallux valgus deformity.

Clerici states that in his experience, the Syme procedure is a good procedure, but is not generally being considered as an alternative to major amputations because of the skill level necessary to address the difficulty in fabricating appropriate foot appliances or prostheses, and managing the complicated biomechanics of the gait post-operatively.

Post-Amputation Load Transfer

With normal ambulation, our feet act as uniquely adapted organs specifically designed for weight-bearing. Following amputation, the residual limb assumes the job of load transfer, adapting to the uneven terrain, providing propulsion during the stance phase of gait, all while utilizing tissues that were not biologically meant for that purpose.

Dr. Michael S. Pinzur, prolific author and authority on foot amputations, states that the most functional lower extremity major limb amputation is the Syme ankle disarticulation.[6] He states that this level allows direct load transfer and end-bearing.

This is achieved in disarticulation amputations at the knee and ankle joint levels, and takes advantage of the normal weight-bearing characteristics of the terminal bone of the residual limb. The overlying soft tissue envelope acts to cushion the bone similar to the function that the heel pad and plantar tissues do in the foot. This is highly conducive to successful weight-bearing on the part from which the distal part is amputated.

In addition, this level is easily accommodated in patients with major volume fluctuation by using a volume-adaptable prosthesis. He goes on to say that patients generally maintain their walking independence with a minimal increased energy cost of walking. In addition, patients normally require only minimal physical therapy with no hospitalization on a rehabilitation unit. He recognizes that although simply empiric, there appears to be no downside risk in patients with soft tissue available for cushioning of the terminal residual limb.

Indirect Load Transfer

Amputations at the transtibial and transfemoral level undergo indirect load transfer, or total contact weight-bearing, in which the surface area and stiffness of the terminal residual limb require unloading. The weight-bearing load must be applied to the entire surface area with a soft tissue envelope acting as a cushion. If the soft tissue envelope is adherent to bone, as is not uncommon in these amputations, the shear forces will produce skin blistering, ulceration, and tissue breakdown.

Ideally, it should be made up of a mobile, non-adherent muscle mass, and full-thickness skin; and could better serve to cushion the underlying bone and dissipate the pressures and forces applied during weight-bearing. Some procedures for leg amputations incorporate flaps that are designed to protect and cushion the underlying bone.

If there is wet gangrene, necrotizing fasciitis, cellulitis or abscess, it would be essential to incise, drain and debride whatever tissues are infected and necrotic immediately, which may include amputating some part of the foot.

Vascular Augmentation

Vascular evaluation and subsequent augmentation should be accomplished before any surgical procedure is performed. Sometimes, how-

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Figure 9: Typical Complication and skin breakdown of a Syme Amputation

ever, the surgical intervention is urgent, where there is no time for extensive vascular intervention and therefore it should be considered after. Notwithstanding these non-elective situations, predictive considerations should begin with assessing the circulation as close to the area of surgical interest as possible.

Amputation wounds generally heal by collateral blood flow.[5] Assessing this can be done with arteriography; however, it is sometimes difficult to determine the exact blood flow at the level of the anticipated surgery. Different methods that are considered by some to be reliable in evaluating the blood flow in the extremity before amputation include the laser Doppler and Doppler ultrasound.

Measurement of pressures using the ankle-brachial index in the lower extremities is often used to assess circulatory status. An ankle-brachial index of 45 in the patient with diabetes has been considered adequate for healing as long as the systolic pressure at the ankle was 70 or higher.

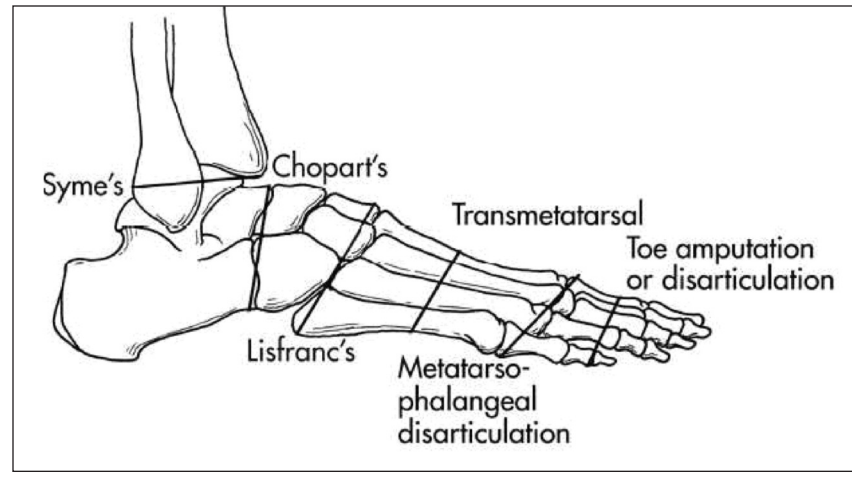

Figure 10: Anatomy of Foot Amputations

These values are falsely elevated and non-predictive in about 15% of patients with diabetes and peripheral vascular disease because of the non-compressibility and noncompliance of calcified arteries in the periphery.

Transcutaneous Oximetry

Many surgeons prefer transcutaneous oximetry (TCPO2) as a measure of the oxygen-delivering capacity to the area of concern. What is recorded is the transcutaneous oxygen tension of the skin at the proposed area of surgery. Values of 50 mmHg and above are considered normal. Values between 40 and 50 mmHg are considered abnormal but still within range for normal healing.

Even though compromise in healing starts below 40 mmHg, values of 30 mmHg or higher have a 90% healing rate. Values between 20-29 mmHg have a 70% healing rate, and values less than 20 are associated with a failure rate of at least 50%.

Transcutaneous oxygen measurements at the skin taken very carefully are very reliable and predictive of surgical success, given awareness of the conditions that may cause a false elevation or reduction from what would be the true measurement. Those factors that directly influence the TcPO2 measurement obtained may be subdivided into four areas: environmental, dermal, physiological, and mechanical.[21] For instance, edema, cellulitis, and technical error could account for an artificially low oxygen value and make the exam invalid.

When TCPO2 measurement is not available, toe pressures are considered an adequate substitute indicator of arterial inflow to the toes and therefore the foot. Toe pressures of 30 mmHg or more are considered the threshold for adequate healing. Also, digital photoplethysmography (PPG) is a simple and reliable imaging test

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FIGURE 11

General Principles Amputations General Principles

- Avoid a 'defeatist' attitude and a desire to complete the procedure as quickly as possible
- Perform with the same level of care and skill as any reconstructive procedure
- Amputation is the first important step in the rehabilitation of a patient with a chronically diseased limb, and hopefully the return of the patient to a productive place in society and the family
- Quality over quantity—do not strive for length at all costs
- Always consider patient age/activity levels / goals
- Bone ends—contouring to prevent pressure points
- Adequate soft tissue cover without excessive bulk
- Balance—muscle/tendon transfer or release as needed
- Grafting may be appropriate to improve soft tissue cover and maintain desired level of amputation •

used to detect changes in blood flow at the microvascular level in the toes, and therefore reflect flow proximally.

In a vascular-compromised patient, surgical or interventional procedures are now commonplace and could establish the circulation enough to allow a window of opportunity for surgical healing. More than one study[7] confirms the increased healing potential with circulation augmentation procedures, where at least 74% of all those patients undergoing interventional or surgical revascularization remain closed in the final evaluation.

Hyperbaric Treatments

Hyperbaric treatments must be considered as an adjunct therapy when treating a patient with marginal vascular status. Hyperbaric treatments will also, by way of effectively increasing the vascularity to an area, potentiate antibiotics and optimize healing in a situation where the delineation of osteomyelitis is unclear.

Prognostic Factors

According to some reports[7] prognostic factors of wound-healing such as white blood cell count, hemoglobin, total lymphocyte count, and albumin were not strictly reliable indicators for healing time after an amputation. Other studies,[7] however, indicated a strong association between failure to heal and leucocytosis, a marker for the severity of infection. An abnormal white blood count was observed in 10% of the limbs in the delayed healing group and 68% of the non-healed limbs.

What is important to realize from this study is that if a patient is infected; and it is a non-emergent situation, then attempting to eliminate the infection, before surgery and after circulation augmentation is accomplished, is the preferred course of action.

In the absence of infection, the lesser amputations were closed primarily. Studies[7] indicate a more favorable outcome within this situation, and resulted in a decreased incidence of a more proximal amputation over those surgeries that were not closed primarily because of infection. In the presence of infection, delayed primary closure was performed after eradication of the infection. Regardless of the variable chances for limb salvage, if a patient is febrile, has an extremely high white blood cell count, positive blood cultures and is septic, it is incumbent upon the surgeon to rid the body of any offending infected tissue as soon as possible.

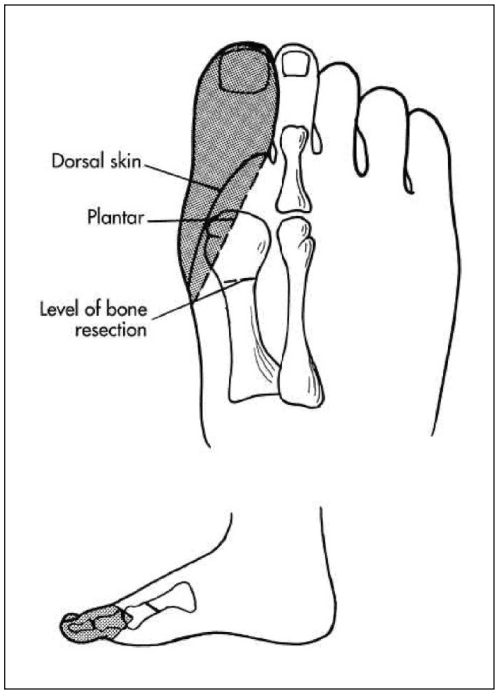

Figure 12: Amputation of the Great Toe

End-Stage Renal Disease

Failure of major limb salvage in patients with end-stage renal disease is thought to be related to wound-healing problems. There is a statistical significance between end-stage renal disease and non-healing of amputation surgeries.[7] This association confirms that end-stage renal disease is a significant predictor of poor healing noted in other studies.[9,10,11,12] In one study[9], 50% of end stage renal disease patients underwent more proximal major amputations as compared with only 20% of persons without the disease.

Nutritional Status

Next, pre-operative review of nutritional status is essential. The importance of nutrition for wound prevention and healing is well established.[13-17] Formulas such as the Harris-Benedict equation, currently used to determine initial amounts of protein necessary, utilize weight, height, age, and gender with an added "stress" factor that takes into account additional requirements for wound healing. Current approaches to address protein malnutrition involve daily intake of 1.5 to 1.8 g/Kg of protein without wound size considerations.

The results of a prospective study of wounded and non-wounded patients indicate that persons with wounds generally require more protein than their non-wounded counterparts.[18]

Agreement is widespread in the literature that nutrition, and especially protein level, is critical for wound healing.[14,15] Protein malnutrition has been implicated as a factor in infections, length of hospitalization, and mortality.

Pre-Albumin Levels

The results of a prospective study of wounded and non-wounded patients indicate that persons with wounds generally require more protein than their non-wounded counterparts.[18] The results of this study confirm the hypothesis that wound patients require higher levels of protein than is commonly recommended for the purpose of elevating pre-albumin levels. The average maximum amount of protein provided to patients whose pre-albumin improved was significantly higher in the wound than in the non-wound group (1.85 g/Kg/day compared to 1.47 g/Kg/day).

Moreover, on admission to this

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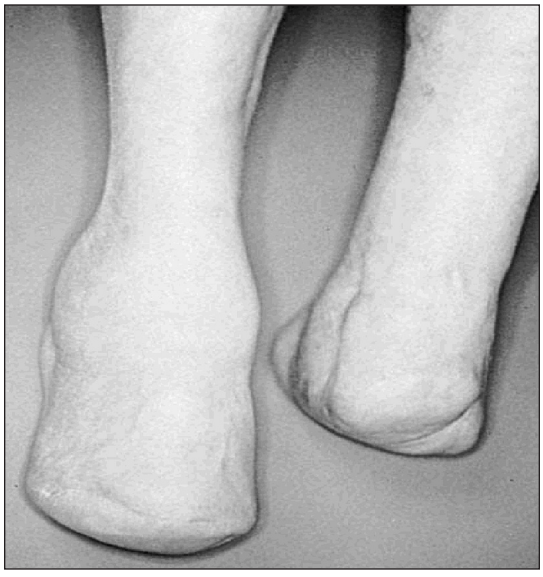
author's facility, only 11 of the 93 wound patients had normal pre-albumin levels. (Normal range is 18.0 to 35.0 mg/dL.) Because estimated protein requirements may vary greatly, the most effective practice is to monitor pre-albumin regularly and adjust protein provision accordingly. Pre-albumin should be measured weekly until protein is normalized; protein intake should be increased if pre-albumin does not rise by 3 or 4 units. Wound patients require a dynamic rather than a static approach, as is possible when using pre-albumin measurements.

Many authors discuss the importance of using serum albumin measurements as an accurate indicator of nutritional and protein status. In the past, albumin was the long-favored marker when measuring protein levels. However, with a half-life of 21 days, albumin is slow to respond to nutrients that a patient has ingested recently. In addition, albumin is affected by many non-nutritional factors and may not give an accurate picture of a patient's true nutritional status.

Figure 14: Cho-part Amputation



Pre-albumin, on the other hand, has a two-day half-life and therefore responds very quickly to a decrease in nutritional intake and nutritional restoration. Pre-albumin has a high concentration of tryptophan, which has been shown to play a key role in the initiation of protein synthesis. It has one of the highest proportions of essential to non-essential amino acids of any protein in the body.

These factors, as well as a short half-life, small body pool, and quick response to lowered protein intake, make it a better indicator of visceral protein status and positive nitrogen balance than albumin and is considered by many nutritional experts to be a more valid indicator of usable protein stores in the body.

Hyperglycemia

Intimately related to nutrition is blood sugar levels and control of diabetes. Hyperglycemia will cause lymphocytes to become sluggish and will deactivate macrophages. High glucose levels have also been associated with other post-operative infections including those of the urinary tract and the respiratory system. Ideal management involves maintenance of glucose levels below 200 mg/dl.5 Many diabetic foot specialists, who are active in limb salvage and performing all types of major and minor amputations, find a correlation between a high HbA1c and success in limb salvage.

A retrospective review of 100 patients with a diagnosis of diabetic foot ulcers who were admitted to a San Diego hospital where this author is on staff, revealed that all of the patients whose limbs were spared had a HbA1c below 8.5. The converse did not hold true. The patients who underwent major amputation had HgA1c values that ranged from 6.5 to 14.

This study concludes that intensive and well-controlled treatment of insulin-dependent diabetes reduced the risk of complications and pathology in diabetic patients.

This is consistent with the experience of Dr. Robert J. Snyder, Professor and Director of Clinical Research and Director of Wound and Research Fellowship Program at Barry University College of Podiatric Medicine. He lectures on this subject and quotes the Diabetes Complications and Control Trial which was conducted by NIDDK from 1983 to 1993. It is the largest and most comprehensive diabetes study ever, and is said to be the most important clinical trial ever conducted in the field of diabetes.

This study concludes that intensive and well-controlled treatment of insulin-dependent diabetes reduced the risk of complications and pathology in diabetic patients. As HbA1C is a measure of blood glucose levels, there is an obvious correlation with healing rates. There are two studies which back up this statement.

The first study[19] was performed to determine the frequency of minor and major amputations in diabetic patients with different Wagner grades of severity and to correlate it with glycemic control, which was determined by baseline fasting and random blood sugar and HbA1c levels. The study concluded that the frequency of minor and major amputation increases with the higher grades of diabetic foot ulcerations and that poor glycemic control is a significant risk

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factor for amputation in diabetic foot patients. The second study[20] demonstrated inhibition of angiogenesis by chronic hyperglycemia, which in turn, negatively affects the potential for new capillary growth and other key components of the wound healing process. It concludes that uncontrolled diabetes, as indicated by high HgbA1c levels, may impede successful outcomes.

In the effort to control blood sugar, however, a balance has to be maintained between caloric reduction and maintenance of protein stores to generate optimum healing for that patient. A minimum of 1,800 calories daily should be provided to avoid a negative nitrogen balance that could accompany depletion of protein stores.

Proper Biomechanics

In addition, according to Dr. Giacomo Clerici, the most important reason for failure of distal amputations is the fact that proper biomechanics are not obeyed. Patients who fail at healing may have not worn the appropriate off-loading devices during healing and appropriate shoes, orthoses, and prosthetic wear after the amputation site is closed and the wound is healed. This may be due to lack of compliance on the part of the patient or inappropriate professional recommendations after the surgery.

At the Centre for the Prevention and Treatment of the Diabetic Foot at the MultiMedica Center in Milan, every patient visits the staff orthotist/prosthetist, who customizes the off-loading devices as well as the patients' shoes, insoles, orthoses and prostheses. Lastly, social and financial concerns, lifestyle habits, home environment, transportation issues and level of compliance must be addressed if success is to be realized.

Pre-operatively, therefore, if you want the most distal amputation to succeed, there are many parameters to be evaluated and adjusted. And given a moderate chance for success, the most distal amputations should be attempted as well as being equipped to deal with the possible complications if major amputation is to be avoided.

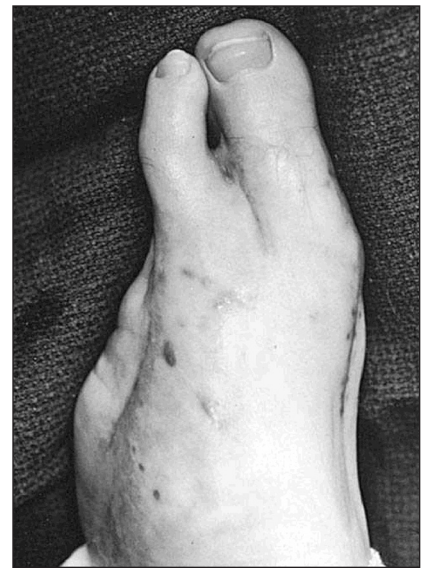

Figure 13: Migration of the second toe when lateral toes are amputated

Making the Decision for Minor or Major Lower Extremity Amputation

In an effort to establish a uniform decision-making process for all types of foot amputations that could be applied consistently among all patients facing amputation, the following issues must be addressed:

1) Decide if there is an emergent situation requiring immediate surgical intervention.

2) Decide on the nature of the emergent surgery.

3) If possible before emergent surgery, perform a vascular workup and procedure to optimize the success of the emergent surgery.

4) After the emergent surgery or in a non-emergent situation, perform any additional and more definitive vascular studies or imaging that are needed.

5) Perform any medical, interventional or surgical vascular augmentation that is needed.

6) Address any areas of cellulitis, infection, and osteomyelitis and differentiate any areas of Charcot process; and select the surgical, nonsurgical or medical treatment of choice and strategy. Determine the risks, the benefits, the time needed for healing, and ancillary modalities that would be needed in a surgical or nonsurgical strategy, and consider such things as hyperbarics, access to home healthcare, transportation needs, etc.

7) Involve the family, caretaker, and any nursing role personnel.

Have a discussion with the patient and/or representatives regarding

a) Ambulatory status

b) Lifestyle

c) Willingness to comply with a potentially rigorous healing and time commitment

d) Compliance regarding post-operative footwear and prosthetics

e) Risks and benefits

f) Direct and indirect costs

g) Career and job status

h) What the patient wants and is willing to make a commitment for

i) Family, friends and social support

j) The psychological makeup of the person and how this person would frame an amputation

It could be established that if a patient has the potential to heal from a minor foot amputation, then a major lower extremity amputation could be avoided.

If the next step is a surgical course:

8) Obtain any consults needed to help formulate a surgical decision, i.e., second opinions, psychiatry, or social service consult, etc.

9) Determine the procedure of choice considering the most distal location of amputation at which chances of healing would be acceptable, areas of diminished circulation status, biomechanics and footwear considerations, as well as choice of

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skin closure or non-closure techniques considering areas of viable skin available and potential for graft or flap success. It is essential to remember the general principals of amputation. (Figure 11)

If the next step is a non-surgical course:

10) Secure reliable and appropriate cultures and sensitivities.

11) Institute appropriate antibiotic therapy if needed.

12) Provide appropriate wound care and off-loading technique.

A true commitment to lower extremity amputation prevention requires addressing the multi-faceted aspects of being human as well as the real world of limited resources.

13) For all patients, engage a patient navigator/family member to arrange for placement to a skilled nursing, long-term care acute facility, homecare or outpatient care.

14) Determine acute care resources regarding dressings, permanent off-loading and shoe/orthoses/prosthetic wear, wheelchair, crutches, transportation, follow-up care after the surgical or non-surgical course has been completed.

15) Determine the overall health and nutritional status of the patient, addressing co-morbidities and follow-up for medical care.

16) Once the adverse event has resolved, it is important to assure rehabilitation of the patient as close to their previous functional level as possible.

17) Always enroll the patient in a primary, secondary, and tertiary prevention program.

Summary

In summary, it could be established that if a patient has the potential to heal from a minor foot amputation, then a major lower extremity amputation could be avoided. A battery of information is needed to determine if the patient is a candidate for limb preservation and salvage. Closing a wound and healing a distal amputation could require a large social, financial, time and psychological commitment. If this commitment is not made, however, it could lead the patient down a more difficult, costly, and unending path of despair.

Nonetheless, no limb preservation or salvage procedure is a panacea. One of the biggest risk factors for a new ulceration is one that has healed. The patient with any form of lower extremity amputation must, therefore, be considered at high risk for another ulceration and possibly amputation. To truly prevent further amputation, an unswerving desire and steadfastness to prevention principles is required for the rest of the patient's life. This necessitates awareness of what is needed, constant education and motivational support, diligent family, caretaker or navigator re-enforcement, careful clinical follow-up, assiduous attention to the biomechanics involved as well as diligence in seeking out and wearing the appropriate shoe, orthotic and prosthetics.

Self-inspection and periodic checkups with a foot care specialist, as well as debridement of keratomas and hypertrophic toenails that may lead to ulcerations and amputations, are absolutely necessary. High on the list is maintaining overall physical conditioning as well as mental and emotional health.

Conclusion

In conclusion, the loss of a limb is tragic and is the beginning of the end for most of the patients who succumbed to a lower extremity amputation. Healthcare practitioners dealing with these diabetic foot problems have a very difficult and answerable job. They have the power to determine a patient's life course, and must not take that lightly and do everything that's possible to save the patient's limb. Doctors must be advocates for their patients and be staunch in making the least life-altering recommendations. A true commitment to lower extremity amputation prevention requires addressing the multi-faceted aspects of being human as well as the real world of limited resources. But above all, those taking on this ominous responsibility must always bear in mind that it could be them or their family member whose life is hanging on the counsel of their doctor. **PM**

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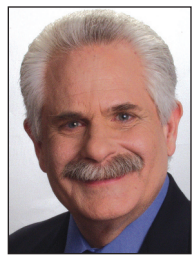

Dr. Rehm, a Diplomate of the American Board of Multiple Specialties in Podiatry and Board Certified in Foot Surgery, Primary Care Medicine in Podiatry, Prevention and Treatment of Diabetic Foot Wounds and in Diabetic Footwear and Board Eligible in Limb Preservation and Salvage, practices in San Diego, CA. He is an active researcher and lectures nationally and offers seminars for podiatrists and other professionals. Dr. Rehm is Director of the Diabetic Foot and Wound Treatment Centers in San Diego and Medical Director of the Cardiovascular, Diabetes and Limb Preservation Alliance.

CME EXAMINATION

Continuing Medical Education

See instructions and answer sheet on pages 178-180.

1) The following is considered a major amputation:
- **A) An above-the-knee amputation**
- **B) A Priogoff amputation**
- **C) A Boyd procedure**
- **D) Sarmiento amputation**

2) A below-the-knee amputation is
- **A) To be avoided at all costs**
- **B) Technically a very difficult and risky procedure**
- **C) Sometimes a life-saving event**
- **D) Rarely associated with intense recuperative and rehabilitative care**

3) Data from several studies indicate
- **A) It is rare to experience a contra-lateral amputation within 12 months after an amputation.**
- **B) A five-year mortality rate following a major amputation of 39-68%.**
- **C) Five years following an initial major amputation, 5% of diabetic amputees have undergone a second leg amputation.**
- **D) TCPO2 measurement is not recommended when a leg amputation is being considered.**

4) Critical factors in assuring the success of a lesser amputation include:
- **A) Blood sugars lower than 125 mg/dl.**
- **B) TCPO2 levels below 20 mmHg.**
- **C) Off-loading the surgical area post-operatively.**
- **D) The climate of the area in which the surgery took place.**

5) Which of the following is the best method of determining the level of foot amputation to be performed?
- **A) Indium 111 WBC scans**
- **B) The level on the foot at which there is adequate hair growth**
- **C) The level at which the patient exhibits loss of protective sensation.**
- **D) TCPO2 testing**

6) Common complications of toe amputations include:
- **A) Development of heloma durum in the adjacent toes.**
- **B) Gouty tophi at the base of the amputation stump.**
- **C) Development of hallux abducto valgus with bunion deformity.**
- **D) Plantar fasciitis as a result of plantar-flexion contractures.**

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7) Amputations at the transtibial and transfemoral level
- A) Require total contact weight-bearing.
- B) Undergo direct load transfer.
- C) Require the weight-bearing load to be applied to only the center of the surface area of the stump.
- D) Do not require a soft tissue envelope because of its location.

8) Amputation wounds generally heal by
- A) Secondary intention.
- B) Collateral blood flow.
- C) Limiting the fibronectin bridging.
- D) Autologous grafting.

9) What range of transcutaneous oxygen tension would indicate normal vascular perfusion?
- A) 50-70 mmHg
- B) 10-15 mmHg
- C) 110-115 mmHg
- D) .8-1.1 mmHg

10) What percent of patients heal from their amputations after undergoing vascular intervention?
- A) 98.4%
- B) 52%
- C) 74%
- D) 34%

11) Hyperbaric treatments result in:
- A) Decreased angiogenesis.
- B) Decreased diabetic dermopathy.
- C) Potentiation of antibiotics.
- D) Polyol/Sorbital pathway activation.

12) The most accurate determination of protein stores immediately available to the healing wound would be the following:
- A) Sulfur colloid bone marrow exam
- B) HbA1c
- C) Albumin
- D) Pre-albumin

13) Persons with wounds or healing from a surgery require:
- A) More protein than their non-wounded counterparts.
- B) More simple carbohydrates than before surgery.
- C) More vitamin K if they are over 50 years of age.
- D) A decrease in dietary fiber.

14) The following is true regarding end-stage renal disease:
- A) Persons with ESRD undergo less proximal amputations than persons without the disease.
- B) It is a significant predictor of poor healing.
- C) It is responsible for protein malnutrition.
- D) ESRD is associated with higher albumin in the blood.

15) Hyperglycemia is associated with the following:
- A) Stimulating the activity of the macrophage and lymphocyte
- B) Decreasing edema and therefore the healing time in post-surgical patients
- C) Infections of the urinary tract and the respiratory system
- D) HbA1c levels below 5.0

16) Ideal Glucose Management involves maintenance of
- A) HbA1c below 12.
- B) Glucose levels below 200 mg/dl.
- C) Glucose levels between 60 and 70 mg/dl.
- D) High CRP levels.

17) One of the most common reasons for failure of distal foot amputations is:
- A) Abnormal capillaries as demonstrated by skin and skeletal muscle biopsy.
- B) Irreversible microcirculatory vasoconstriction.
- C) Lack of appropriate foot wear and prosthetics.
- D) Chronic low-grade inflammation.

18) Arterial vascular evaluation should be done
- A) While the limb is dependent.
- B) After differentiation is made between Charcot deformity and osteomyelitis.
- C) At the distal end of gangrenous toes.
- D) Before any amputation is performed.

19) The psychological makeup of the person
- A) Should always be involved in the pre-surgical conversations before any amputations.
- B) Is responsible for the accumulation of glycoxidation and lipoxidation products in the body.
- C) Should never be part of the decision process of where to amputate.
- D) Does not affect the patient's ability to heal.

20) One of the biggest risk factors for a new ulceration and amputation is:
- A) Lack of marrow edema on MRI.
- B) A large difference between the T1 and T2 weighted images.
- C) A neuropathic ulceration that has already healed.
- D) Painful bilaterally symmetrical ulcerations.

SEE INSTRUCTIONS AND ANSWER SHEET ON PAGES 178-180.