



High-risk foot and ankle patients

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The restoration and preservation of function, while providing pain relief, remains a fundamental goal in foot and ankle surgery. In recent years, many advances have been made in this area. Complicated injuries, such as calcaneus and pilon fractures, often are treated surgically. Surgical reconstruction of complex deformities, such as posterior tibial dysfunction and charcot arthropathy are now performed. The expectations of our aging population also provide new challenges in the restoration of function. Technological changes have provided new opportunities for treatment of difficult problems; however, the advantages of these treatments can be limited by associated complications. Careful preoperative evaluation and patient selection is fundamental to the reduction of risks that are associated with surgery. Awareness of patient-related variables that may increase the risk of complications should allow for better preoperative planning.

Preoperative assessment is performed on patients to identify treatable comorbid conditions and correction of conditions that may not have been recognized previously [1]. The evaluation of cardiopulmonary status is very important in the determination of surgical risk [2]. Cardiac risk is highest in patients who have had a myocardial infarction less than 6 months before surgery, pulmonary edema within 6 months, unstable angina or angina with minimal exertion, and those with aortic stenosis [1]. These patients require formal cardiac evaluation before proceeding with elective foot and ankle surgery. A recent study noted five factors that increase the mortality risk that is associated with orthopedic surgery; these include chronic renal failure, congestive heart failure, chronic obstructive pulmonary disease, hip fractures, and age greater than 70. The investigators noted that the overall mortality rate for orthopedic procedures was 1%. In their

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study, no mortalities were associated with foot and ankle admissions; however, the number of patients in this subgroup was relatively small. Preoperative screening through a history and physical examination is important in identifying patients who would benefit from more extensive medical evaluation before proceeding with surgical intervention.

Diabetes

It has been estimated that 16 million people in the United States have diabetes mellitus [3]. It is a multisystem disorder that can have a profound effect on the patient's overall health. Foot and ankle problems are an area of significant concern in diabetic patients. The foot and ankle are besieged by a combination of peripheral neuropathy and peripheral vascular disease that can lead to problems in the treatment of diabetic patients. In addition, diabetes can have significant metabolic effects (eg, decreasing collagen synthesis, impairing cellular proliferation and granulocyte function) [4]. It is estimated that 25% of the hospital admissions of diabetic patients are related to problems with their feet [5]. A review of a diabetic outpatient clinic noted that 68% of patients had some structural pathology associated with the foot [6]. Most of the structural changes were mild, such as the presence of hammertoes and callus formation. Forefoot pathology was found to be significant in another study as most amputations in diabetics occur for lesions around the digits [7]. Approximately 34% of patients in this study were insensate; 41% of patients with insensate feet were unaware of their sensory deficit. Twenty-five percent of patients had autonomic neuropathy. The combination of neuropathy and abnormal pressure, which may be compounded by the presence of deformity, can lead to ulcerations in the foot or ankle. Ulceration can start a cascade of events that lead to the development of infections within the foot and ankle, that, in turn, can threaten limb viability.

The evaluation of patients for sensory deficits with Semmes-Weinstein monofilament and the use of protective footwear is essential to minimizing complications [8]. Continued evaluation of diabetic patients is needed because the recurrence rate for a new ulcer after healing a previous ulcer is 34% at 1 year, 61% at 3 years, and 70% at 5 years [9]. Patients who required an amputation to heal their ulcer had a higher recurrence rate than those who healed primarily. The mortality rate was two times higher in patients who healed primarily and four times higher in patients who healed with an amputation compared with age- and sex-matched controls.

Approximately 40% of diabetic patients will have a peripheral neuropathy, and, of those patients, as many as 2.5% will develop charcot changes [10,11]. Charcot arthropathy or neuroarthropathy describes a progressive destruction of joint integrity as a result of disturbance in normal pain and proprioception combined with repetitive stress. This process can lead to significant deformity and instability in the foot and ankle. Early recognition of the neuroarthropathic process is important to protect the limb and to minimize the subsequent

development of instability or deformity. The instability or deformity that is associated with neuroarthropathy leads to abnormal pressure distribution which can result in ulcer formation. The resulting deformity or instability can make bracing or shoe accommodation extremely difficult. Surgical management may be required in recalcitrant cases as a method of foot salvage [12,13].

Although most ulcers that are seen in diabetic patients are the result of neuropathy, the vascular status of the patient can play a significant role in the outcome of ulcer management. Given adequate vascularity, most ulcerations can be treated with pressure relief and protection of the limb. Lack of blood flow to a limb can lead to the inability to heal wounds. It is imperative that the vascular status of the patient be evaluated because diabetic patients often have associated peripheral vascular disease. The risk of peripheral vascular disease increases with time in diabetic patients. Approximately 15% of patients will have peripheral vascular disease 10 years after the onset of diabetes mellitus; at 20 years after onset, the incidence increases to 45% [14]. In addition, the arterial disease that is found in diabetic patients is usually more severe than that which is found in nondiabetic patients [15]. Consultation with a vascular surgeon and appropriate revascularization can be instrumental in reducing the complications and risks that are associated with the treatment of foot and ankle problems in diabetic patients.

The surgical stabilization of fractures in diabetic patients can be associated with a significant complication rate. Complication rates as high as 43% were noted with the operative management of ankle fractures [16]. Patients with ankle fractures that were treated with casting had a higher infection rate than the control group [17].

Patients with diabetes have a 15 times higher risk of lower extremity amputation than nondiabetic individuals [18]. Some risk factors for amputation in diabetics include ankle-arm blood pressure index less than 0.45, absence of lower leg vibratory perception, low levels of high-density lipoprotein, and no previous outpatient diabetes education [19]. Diabetic patients with chronic renal failure are at an increased risk for amputation [20,21]

Minimizing the complications in the treatment of foot and ankle problems in the diabetic patient requires recognition of the neuropathic and charcot changes, implementation of appropriate protocols for charcot injury, appreciation for associated medical conditions, and the use of appropriate preventative care. A multidisciplinary approach between orthopedic surgery, vascular surgery, endocrinology, nursing, and pedorthotists that emphasizes appropriate control of blood glucose levels, maintaining adequate blood flow, minimizing deformity, patient education, and appropriate protective footwear are essential in optimizing the treatment of the high-risk, diabetic patient.

Cigarette smoking

Smoking is considered the leading avoidable cause of morbidity and mortality in the United States [22]. Smoking has been implicated as risk factor for increased complications in the treatment of foot and ankle problems [23–27].

Wound healing is a concern in the surgical management of patients who smoke [22,23,28]. A study of patients who underwent open reduction and internal fixation of calcaneus fractures revealed that smoking delayed the rate of wound healing [23]. Nicotine, found in cigarette smoke, was shown to increase platelet aggregation, decrease microvascular prostacyclin levels, and inhibit the function of fibroblasts, red blood cells, and macrophages [28]. The carbon monoxide that is found in cigarette smoke has a stronger affinity for hemoglobin than oxygen which leads to lower oxygen tension in tissues [29]. A decrease in cutaneous blood flow in subjects who are exposed to nicotine or cigarette smoke was noted. These changes are believed to interfere with the natural process of wound healing and lead to an increased complication rate in smokers.

In addition to its effect on wound healing, smoking is also believed to affect bone healing. Cobb et al [24] evaluated the effect of smoking on bone healing after ankle arthrodesis; the relative risk of nonunion for smokers was 16 times the risk of nonunion for nonsmokers. Perlman and Thordarson [21] noted a trend toward nonunion in smoking patients who underwent ankle fusion. A review of patients who underwent subtalar arthrodesis revealed that smokers had a higher tendency for nonunion compared with nonsmokers [30]. De Vernejoul et al [31] suggested that smoking impairs osteoblast function which leads to normal bone resorption but decreased bone formation. Campanile et al [32] postulated that the effect of smoking is the result of vessel vasoconstriction, tissue hypoxia, and inhibition of cellular oxidative metabolism that is mediated by the various compounds that are contained in cigarette smoke.

No study provides definitive guidelines about the perioperative cessation of smoking [27]. Campanile et al [32] noted that smoking cessation recommendations ranged from 1 day to 3 weeks preoperatively and from 5 days to 4 weeks postoperatively. Abidi et al [23] suggested that cessation of smoking 5 days before surgery increased the rate of wound healing. Most of the evidence suggests that smoking can have a negative effect on the treatment of foot and ankle problems. Encouraging the cessation of smoking before elective surgical treatment may be warranted to minimize complications. The risk that is associated with cigarette smoking deserves consideration in risk/benefit analysis regarding surgical intervention.

Peripheral vascular disease

Adequate vascular supply to the foot and ankle is a critical factor in the outcome of patient treatment [12]. It is imperative that the status of the patient's blood supply be considered before proceeding with treatment. Those patients with inadequate blood flow are at high risk for complications, and possibly limb loss, following surgical treatment [33]. Wound hypoxia, as a result of poor blood flow, is detrimental to healing because it limits fibroblast replication and impairs collagen production [34]. Thus patients with significant vascular disease have a poor capacity to heal a wound.

Evaluation of the patient's vascular status begins with a clinical assessment and is confirmed with further testing. Patients with chronic arterial occlusion often have an aching or cramp-like sensation in the calf that is associated with exercise. Patients with diffuse arterial disease can also present with exercise-induced foot and ankle pain [33]. The pain may be described as an aching discomfort that is associated with stiffness in the foot and ankle. Patients with more advanced arterial disease may complain of a more diffuse, forefoot pain that is present at night. The patients often get pain relief from swinging their foot over the edge of the bed or getting up and walking around [33].

Examination should focus on evaluation of peripheral pulses. Pulses in the groin, popliteal, and pedal areas should be palpated. The presence of bruits in these areas may suggest early occlusive disease. Patients with more advanced disease may present with a lack of hair growth on the dorsum of the foot, thickening of the toenails, and delayed capillary refill. A thin, pale foot may be associated with ischemic changes. Advanced cases may show evidence of ischemic ulceration or gangrene.

If the clinical assessment suggests the presence of peripheral vascular disease then further evaluation with use of the vascular laboratory may be indicated. The ankle to brachial index (ABI) is a simple screening method that is widely used in clinical practice. Normally, the ABI should be 1.0 or higher. Values less than 0.9 are considered abnormal; values less than 0.45 may indicate inadequate blood flow for healing. Some care must be taken when interpreting this data because ABI may be falsely elevated in persons with significant calcification within the vessels, such as diabetic patients. In cases where ABI may be falsely elevated, it is valuable to evaluate the pulse volume recording (PVR). Qualitative evaluation of these recordings will indicate the presence or absence of pulsatile flow into the foot [5]. Transcutaneous oxygen pressure (TCPO₂) measurements, if done under the appropriate conditions, can be helpful in determining whether local tissue perfusion is sufficient to permit healing [12]. Patients who have TCPO₂ values less than 40 mm Hg are poor candidates for foot reconstructive procedures until their vascular status can be improved. Absolute toe pressures also provide information about end-arterial flow. Absolute pressures greater than 45 mm Hg are indicate adequate blood flow to permit surgical healing [5]. Appropriate clinical evaluation, in combination with these studies, can help to identify high-risk patients who may benefit from evaluation and treatment by a vascular surgeon before proceeding with reconstruction of their foot or ankle.

Trauma

Lower extremity trauma can be the cause of significant morbidity for patients. High energy trauma can lead to significantly comminuted fractures and compromise of the surrounding soft tissue envelope. The soft-tissue coverage over the distal, lower extremity is relatively thin which increases the chances of compromise as a result of injury. Traumatic injuries of the foot and ankle, such as calcaneus

and tibial plafond fractures, have been associated with a high rate of complications [35–37]. Open fractures compromise the protective skin barrier and increase the risk of associated infection. In addition, the devitalization of tissues that occur in open fractures can limit or impair healing potential. Poorly planned operative intervention can result in further injury to an already compromised situation.

A history of high energy, open injury was associated with an increased complication rate in later reconstructive procedures. Perlman and Thordarson [26] noted that 53% of patients who underwent an ankle fusion for posttraumatic arthritis, following an open fracture, developed a nonunion. This was believed to have occurred because higher energy injuries cause more damage to the soft tissue and the blood supply of the bone. Easley et al [30] noted that avascular bone at the subtalar joint can lead to increased rates of nonunion in subtalar fusions. Frey et al [38] noted that the presence of avascular necrosis was a risk factor for nonunion in ankle fusions. Recognition that trauma and posttraumatic problems have resulted in injury to the soft tissues and bone is important in minimizing risk. In many cases, surgical intervention may need to be delayed until soft tissue compromise is diminished. The use of minimally invasive techniques and staged treatment protocols may help to diminish associated risks.

Nutrition

Malnutrition has been a relatively underappreciated risk factor in the management of orthopedic patients. Jensen et al [39] noted that approximately 40% of patients who underwent orthopedic surgery had evidence of malnutrition. Poor nutritional status can have a profound effect on immune function and a negative impact on the ability of patients to heal [40]. Kay et al [41] noted that patients who were malnourished had an overall complication rate of 48% after undergoing below-the-knee amputations compared with a 7% complication rate in the well-nourished group. In addition, stress, such as trauma, surgery, or infection, can increase metabolic needs almost threefold [42]. This emphasizes the importance of nutritional screening in patients who undergo surgery.

The use of body weight as a major indicator of nutritional status is relatively insensitive to marginal protein depletion [39]. Adequate protein stores are important in wound healing and immune function. The use of serum albumin levels and total lymphocyte counts are reliable in screening for nutritional deficiencies [28,39,40,42]. A serum albumin less than 3.5g/dl was associated with poor healing and increased complication rates. The total lymphocyte count is calculated as a percentage of lymphocytes multiplied by the white blood cell count. Total lymphocyte counts less than 1500 cells per cubic millimeter are consistent with impaired cellular defense mechanisms and malnutrition [28]. Jensen et al [39] suggested that patients with a history of recent unintentional weight loss, a surgical procedure within 6 months, and either a serum albumin less than 3.4 g/dl or a total lymphocyte count less than 1500 cell/ml³ should have elective procedures delayed and should undergo a more complete nutritional

evaluation. The detection and correction of nutritional deficiencies may play an important role in minimizing complications that are associated with foot and ankle surgery.

Additional considerations

Patients with a history of alcoholism were noted to have an increased complication rate in the treatment of ankle problems [26,43]. In addition, many of these patients have some degree of peripheral neuropathy and peripheral vascular disease, similar to diabetic patients. It is believed that decreased immune defense, inhibited wound healing, and defective osteoblastic function that is induced by ethanol contribute to the increased morbidity that is seen in these patients [43]. It was also suggested that poor compliance with instructions may also be a factor in the increased morbidity [26].

Patients who are on glucocorticosteroids are at an increased risk for healing problems following surgical treatment [40,44]. Steroids impair fibroblast proliferation and collagen synthesis. Granulation tissue formation is also decreased. This may lead to wound problems in the postoperative period. Additional patient characteristics that have been suggested as risk factors for postoperative complications, include persistent lower extremity edema, chronic skin changes, history of radiation treatment, use of chemotherapy, psychiatric illness, advanced liver disease, and immunocompromise [40,44].

Summary

The surgical treatment of complicated foot and ankle problems requires recognition and appreciation of patient and disease characteristics that may compromise surgical results. Appropriate patient selection is an important factor in obtaining a successful outcome. Modulation and management of these patient characteristics are critical in minimizing complications that are associated with treatment.

References

- [1] Fiorillo AB, Rubash HE. Perioperative medicine. In: Beaty JH, editor. *Orthopaedic knowledge update 6*. Rosemont (IL): American Academy of Orthopaedic Surgeons; 1999. p. 73–9.
- [2] Bhattacharyya T, Iorio R, Healy W. Rate of and risk factors for acute inpatient mortality after orthopaedic surgery. *J Bone Joint Surg* 2002;84A(4):562–72.
- [3] Siller TA, Calhoun JH, Muder JT. Diabetic foot infections: active intervention to preserve function. *J Musculoskeletal Med* 1996;11:43–55.
- [4] Macey LR, Kana SM, Jingushi S, et al. Defects of early fracture healing in experimental diabetes. *J Bone Joint Surg Am* 1989;71A:722–33.
- [5] Brodsky JW. The diabetic foot. In: Coughlin MI, Mann RA, editors. *Surgery of the foot and ankle*. 7th edition. St. Louis: Mosby; 1999. p. 895–969.
- [6] Holewski J, Moss K, Stess R, et al. Prevalence of foot pathology and lower extremity complications in a diabetic outpatient clinic. *J Rehab Res Dev* 1989;26(3):35–44.

- [7] Isakov E, Budoragin N, Shenhav S, et al. Anatomic sites of foot lesions resulting in amputation among diabetics and non-diabetics. *Am J Phys Med Rehabil* 1995;74(2):130–3.
- [8] Umeh L, Wallhagen M, Nicoloff N. Identifying diabetic patients at high risk for amputation. *Nurse Pract* 1999;24(8):56–63.
- [9] Apelqvist J, Larsson J, Agardh C. Long-term prognosis for diabetic patients with foot ulcers. *J Int Med* 1993;233:485–91.
- [10] Kumar S, Ashe HA, Parnell LN, et al. The prevalence of foot ulceration and its correlates in type 2 diabetic patients: a population-based study. *Diabet Med* 1994;11(5):480–4.
- [11] Marks RM. Complications of foot and ankle surgery in patients with diabetes. *Clin Orthop* 2001;Oct(391):153–61.
- [12] Early JS. Surgical intervention in diabetic neuroarthropathy of the foot. *Foot Ankle Clin* 1997; 2(1):23–36.
- [13] Papa J, Myerson M, Girard P. Salvage, with arthrodesis, in intractable diabetic neuropathic arthropathy of the foot and ankle. *J Bone Joint Surg Am* 1993;75A(7):1056–66.
- [14] Melton LJ, Macken KM, Palumbo DJ, et al. Incidence and prevalence of clinical peripheral vascular disease in a population based cohort of diabetic patients. *Diabetes Care* 1980;3(6): 650–4.
- [15] Jude EB, Oyibo SO, Chalmer N, et al. Peripheral arterial disease in diabetic and nondiabetic patients: a comparison of severity and outcome. *Diabetes Care* 2001;24(8):1433–7.
- [16] Blotter RH, Connolly E, Wason A, et al. Acute complications in the operative treatment of isolated ankle fractures in patients with diabetes mellitus. *Foot Ankle Int* 1999;20(1):687–94.
- [17] Flynn J, Rio R, Piza P. Closed ankle fractures in the diabetic patient. *Foot Ankle Int* 2000;21(4):311–9.
- [18] Most RS, Sinnock P. The epidemiology of lower extremity amputation in diabetic individuals. *Diabetes Care* 1983;6(1):87–91.
- [19] Reiber GE, Pecoraro RE, Koepsell TD. Risk factors for amputation in patients with diabetes mellitus. a case-control study. *Ann Intern Med* 1992;177(2):97–105.
- [20] Eggers PW, Gohdes D, Pugh J. Nontraumatic lower extremity amputations in the medicare end-stage renal disease population. *Kidney Int* 1999;56(4):1524–33.
- [21] McGrath N, Curran B. Recent commencement of dialysis is a risk factor for lower-extremity amputation in a high-risk diabetic population. *Diabetes Care* 2000;23(3):432–43.
- [22] Skurmik Y, Shoenfeld Y. Health effects of cigarette smoking. *Clin Dermatol* 1998;16:545–56.
- [23] Abidi N, Dhawan S, Gruen G, et al. Wound-healing risk factors after open reduction and internal fixation of calcaneal fractures. *Foot Ankle Int* 1998;19(12):856–61.
- [24] Cobb T, Gabrielsen T, Campbell D, et al. Cigarette smoking and nonunion after ankle arthrodesis. *J Foot Ankle* 1994;15(2):64–7.
- [25] Donley B, Ward D. Implantable electrical stimulation in high-risk hindfoot fusions. *Foot Ankle Int* 2002;23(1):13–8.
- [26] Perlman M, Thordarson D. Ankle fusion in a high risk population: an assessment of nonunion risk factors. *Foot Ankle Int* 1999;20(8):491–6.
- [27] Porter S, Hanley E. The musculoskeletal effects of smoking. *J Am Acad Orthop Surg* 2001; 9(1):9–17.
- [28] Jorgensen LN, Kallehave F, Christensen E, et al. Less collagen production in smokers. *Surgery* 1998;123:450–5.
- [29] Leow YH, Maibach HI. Cigarette smoking, cutaneous vasculature and tissue oxygen. *Clin Dermatol* 1998;16:579–84.
- [30] Easley M, Trnka H, Schon L, et al. Isolated subtalar arthrodesis. *J Bone Joint Surg* 2000;82A(5):613–24.
- [31] De Vernejoul MC, Bielakoff J, Herve M, et al. Evidence for defective osteoblastic function: a role for alcohol & tobacco consumption in osteoporosis in middle-aged men. *Clin Orthop* 1983; 179:107–15.
- [32] Campanile G, Hautmann G, Lotti T. Cigarette smoking, wound healing and face lift. *Clin Dermatol* 1998;16:575–8.

- [33] Queral LA. Evaluation and treatment of vascular insufficiency. In: Myerson M, editor. Foot and ankle disorders. Philadelphia: WB Saunders; 2000. p. 399–410.
- [34] Belkin M, Whittemore A, Donaldson M, et al. Vascular. In: Townsend C, Sabiston OC, editors. Textbook of surgery. The biological basis of modern surgical practice. 16th edition. Philadelphia, PA: W.B. Saunders Co; 2001. p. 1374–80.
- [35] Ovadia DN, Beals RK. Fractures of the tibial plafond. *J Bone Joint Surg Am* 1986;68A(4): 543–51.
- [36] Sanders R. Displaced intra-articular fracture of the calcaneus. *J Bone Joint Surg Am* 2000; 82A(2):225–50.
- [37] Teeny SM, Wiss DA. Open reduction and internal fixation of tibial plafond fractures. Variables contributing to poor results and complications. *Clin Orthop* 1993;292:108–17.
- [38] Frey C, Halikus NM, Vu-Rose T, et al. A review of ankle arthrodesis: predisposing factors to nonunion. *Foot Ankle Int* 1994;15(11):581–4.
- [39] Jensen JE, Jensen TG, Smith TK, et al. Nutrition in orthopedic surgery. *J Bone Joint Surg Am* 1982;64A(9):1263–72.
- [40] Phillips L. Wound healing. In: Townsend C, Sabiston, editors. Textbook of surgery. The biological basis of modern surgical practice. 16th edition. Philadelphia, PA: W. B. Saunders Co; 2001. p. 131–44.
- [41] Kay SP, Moreland JR, Schmitter E. Nutritional status and wound healing in lower extremity amputations. *Clin Orthop* 1987;217:253–6.
- [42] Smith TK. Nutrition: its relationship to orthopedic infections. *Orthop Clin North Am* 1991;22(3): 373–7.
- [43] Tonnesen H, Pedersen A, Jensen M, et al. Ankle fractures and alcoholism. The influence of alcoholism on morbidity after malleolar fractures. *J Bone Joint Surg Br* 1991;73B:511–3.
- [44] Ramasastry SS. Chronic problem wounds. *Clin Plastic Surg* 1998;25(3):367–96.