Special Considerations in the Management of Diabetic Ankle Fractures

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Abstract

Purpose of Review Ankle fractures and diabetes mellitus are both increasing in prevalence. Patients with both diabetes and an ankle fracture have been shown to have an increased rate of complications which can be catastrophic. The purposes of this review are to identify factors placing patients at an increased risk and offer guidance on the management of these injuries, in order to reduce potential complications.

Recent Findings Non-operative management of unstable ankle fractures in patients with diabetes results in an unacceptably high rate of complications. Operatively managed patients with uncomplicated diabetes seem to fair as well as patients without diabetes. Thus, it is important to recognize patients as either complicated or uncomplicated at the onset of their treatment based on comorbidities.

Summary There is limited evidence to guide the management of ankle fractures in patients with diabetes, in particular those deemed complicated. Non-operative management of unstable fractures in diabetic patients should be avoided.

Keywords Diabetic ankle fracture · Charcot neuroarthropathy · Ankle fracture complications · Ankle fracture fixation

Introduction

Ankle fractures are one of the most common orthopedic injuries in the world, with approximately 187 fractures per 100,000 people per year [1]. This rate is rising with the popularity of high-level sports and an ever-aging population. These injuries may be especially devastating in high-risk populations, such as the geriatric population and those with diabetes. With an increasing focus in the medical community on complication prevention and cost control, the management of diabetic ankle fractures has been of significant interest. These patients have been shown to incur a higher proportion of

complications and, subsequently, a perceived higher cost of care. With the preservation of limbs often at stake, there are few more challenging populations from a foot and ankle standpoint than the ankle fracture in a patient with diabetes. According to the ADA, in 2015, the rate of diabetes in the USA is roughly 9.4% of the population or 30.3 million Americans [2]. One quarter of Americans over the age of 65 have a diagnosis of diabetes and 84.1 million over the age of 18 are pre-diabetic [2]. Medical expenses for diabetic patients tend to be over two times higher than non-diabetics and the total cost of diabetes management was approximately \$245 billion dollars in 2012 [2]. Specifically, mean length of hospital stay and healthcare cost of ankle fractures of patients with diabetes have been found to be significantly higher ($p < 0.01$). More specifically, patients with complicated diabetes had longer (2.4 days) hospital stays ($p < 0.01$) and were \$6895 more costly than uncomplicated diabetic patients [3]. These patients also tend to have other medical comorbidities including end-stage renal disease (ESRD), peripheral vascular disease, coronary artery disease, neuropathy, and obesity. These comorbidities can make surgery and post-operative management difficult for even the most skilled surgeon and place them into a more “complicated” category. While there is an increasing volume of knowledge in the management of diabetic patients with orthopedic conditions, there

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is little high-level evidence to guide surgical management and decision-making regarding diabetic ankle fractures.

Non-operative vs. Operative Management

The impact of diabetes on the overall outcome in non-operative and operatively managed ankle fractures is not completely clear. While fracture pattern, stability, and displacement have been the key factors for determining whether operative intervention is necessary, it is important to recognize that these factors may carry a different weight in the setting of comorbidities such as diabetes, increased age, obesity, peripheral arterial disease, and non-ambulatory patients.

Both diabetes and obesity have been shown to portend an increased risk of wound healing complication in operatively treated patients [4]. In an effort to determine what patients may be at a high risk of re-operation after ankle fracture surgery, Pincus et al. reviewed a series of over 45,000 patients with ankle fractures over a 7-year period [5•]. Eight thousand nine hundred six re-operation surgeries (19.6%) were identified. While this number may seem alarmingly high, 92.4% of these re-operations were performed for isolated hardware removal unrelated to infection. Importantly, they found that patients with diabetes were statistically more likely to require re-operation for irrigation and debridement (I&D) ($p < .001$) and amputation ($p < .001$) with median time to I&D and amputation being 100 and 135.5 days, respectively.

While it is generally accepted that stable, isolated malleolar non-displaced injuries can be managed non-operatively in the general population, there remains a question as to whether overall stability and fracture pattern can be adequately assessed by traditional means in this patient population. Further, a stable fracture pattern may not preclude the development of Charcot neuroarthropathy and there is no research to date as to how pre-emptive fixation may increase or decrease the likelihood of developing an active, unstable Charcot event. Stability of these fractures and determination of operative necessity may also be aided by CT scan. Kumar et al. found that routine computed tomography (CT) scans of malleolar fractures prompted a change in medical decision-making in 23.2% of cases [6•]. This may be of particular utility in high-risk populations and we recommend liberal use of CT as a treatment planning tool in this patient population (Figs. 1, 2, 3, and 4).

Patients with isolated malleolar fractures without instability determined by fracture pattern and/or gravity stress radiographs can be treated non-surgically in a CAM boot for continuous monitoring of the skin for potential complication or in a well-padded cast applied by properly trained physician, resident, or medical assistant. It is the authors' standard practice that these patients be monitored at no longer than 14-day intervals with serial imaging and skin checks to assess patients

Fig. 1 A 54-year-old insulin-dependent female treated non-surgically at an outside facility for a ground level fall, presenting for ankle pain and deformity 8 months after injury. Patients with diabetes, peripheral neuropathy, and ankle fractures should be monitored closely with serial imaging for the development of Charcot neuroarthropathy so as to facilitate timely intervention as needed before deformity progresses

for early-onset displacement, Charcot, or skin complications. CAM walkers facilitate skin monitoring, are less labor intensive, and may decrease cost. However, the risk of non-compliance may be significantly higher, especially in the neuropathic patient. Providers must ensure that casts are adequately padded and properly applied to prevent further wound complications on the toes, heel, and shin.

It is also important to note that adequate clinical examination of these patients may be obscured by peripheral neuropathy. The Michigan Neuropathy Screening Instrument is a validated scoring instrument for detecting peripheral

Fig. 2 A seemingly innocuous non-displaced Weber B distal fibula fracture in a 72-year-old female with insulin-dependent diabetes, COPD, and peripheral arterial disease. This patient was a minimal home ambulator. She did have peripheral neuropathy and was immobilized and recommended to be discharged to a skilled facility due to fall risk

Fig. 3 This same patient presenting 10 days later. X-rays now reveal displacement at the medial malleolus and a trimalleolar ankle fracture

neuropathy and the authors recommend the routine use of this instrument to adequately evaluate patients who may be at risk for neuropathic-related complications such as cast-induced ulceration or Charcot neuroarthropathy [7].

Historically, there has been an aversion to the operative management of ankle fractures in patients with diabetes (Fig. 1). The prudence of this approach has become increasingly questioned. In a 2017 study, Lovy et al. determined that patients with displaced ankle fractures have “unacceptably high complication rates” when treated non-operatively with a 75% complication rate [8•]. This suggests that unstable,

Fig. 4 The same patient 4 months post-operatively after undergoing closed application of an intramedullary nail. The patient was permitted to weight-bear 3 weeks post-operatively for pivot and transfers and then permitted full weightbearing in a walking boot 6 weeks after surgery

displaced ankle fractures do benefit from fracture stability with surgical fixation despite the increase in risk for perioperative complications.

Patients who sustain unstable ankle fractures should undergo surgical intervention with the knowledge that they are more prone to complications. Several studies have shown that patients with diabetes are more likely to develop infections. Schade et al., in 2016, looked at patients undergoing repair of closed malleolar fractures between 2006 and 2013 and found that those with insulin-dependent diabetes had a 2.6 greater odds of developing an early post-operative infection [9]. Their study supported previous findings that patients with diabetes have higher post-operative infection risks [10–14]. A study by Haddix et al. in 2017 also looked at the role of insulin dependence and type 1 versus type 2 diabetes in patients with ankle fractures. The study analyzed operative and non-operatively treated ankle fractures from an insurance database, between 2007 and 2014. Those with type 1 diabetes had higher complication rates versus those with type 2 diabetes. In addition, those on insulin tended to have higher complication rates [15].

Increased duration of immobilization has been theorized to decrease the incidence of complications among the diabetic ankle fracture population [16–23]. Some newer literature has aimed to challenge this theory, also positing that early protected weightbearing may limit deconditioning and prevent other perioperative complications [24]. Bazarov et al. in 2017 looked at 48 operatively managed diabetic ankle fractures which were permitted to start protected weightbearing at 2 weeks, finding a 25% complication rate. This was lower than previous reports in the literature on traditional 6–8 weeks of non-weightbearing. This study is limited to only 48 surgically repaired diabetic ankle fractures but concluded that in a small subset of patients, early weightbearing can occur without additional risks. It should be noted, however, that in their report, patients older than 60 years of age had a statistically significant increase in complications ($p = 0.0403$) and this is also the most likely population to become deconditioned with prolonged immobilization. Thus, further research in this area is necessary.

Other considerations are obesity and upper body deconditioning. These issues can be common in patients with diabetes, making lower extremity weightbearing restrictions challenging. Chiodo et al. in 2016 looked at patient compliance with non-weight bearing restrictions after surgery and found that 27.5% of patients were non-compliant with weightbearing restrictions and almost half experienced an adverse event because of not following instructions. Thus, extra attention must be paid in this high-risk population to discharge planning and post-operative care. These patients are more likely to require extra assistance or post-discharge placement to limit issues with non-compliance.

Fixation Choices

If it is generally agreed that the worst-case scenario after open reduction with internal fixation of diabetic ankle fractures is the development of Charcot neuroarthropathy or the necessity of amputation, then it stands to reason that adhering to common practices in the management of Charcot and limb salvage should apply to the management of diabetic ankle fractures. Thus, the authors have adopted a “modified super construct” approach to the fixation and management of diabetic ankle fractures. Sammarco and colleagues defined a super construct with regard to Charcot surgery as fixation meeting the following criteria [25].

1. Fusion is extended beyond the zone of injury.
2. Bone resection is performed to allow for reduction of deformity and relief of soft tissue tension.
3. The strongest device that soft tissue envelope will allow should be utilized for fixation.
4. Fixation should be applied in a manner that maximizes mechanical function.

These can be modified to apply to diabetic ankle fractures with the goals of extending fixation beyond the immediate zone of injury, planning incisions to allow for fixation placement in low-risk intervals for healing, utilization of the strongest available fixation device, and application of the device in a mechanically advantageous fashion (i.e., anti-glide plating). The advent of locking plate technology has revolutionized the orthopedic landscape. It allows surgeons to have better fixation while preserving vital periosteal blood supply, which is crucial for fracture healing. These plates achieve mechanically superior fixation, often without increased fixation volume. In addition to locked plating technology, the utilization of multiple four-cortical syndesmotic screws has been suggested [26].

Fig. 5 A 57-year-old male with type 2 diabetes, obesity and peripheral neuropathy treated with ORIF with use of locked plating, multiple syndesmotic screws, and a supplementary medial anti-glide plate

It is the authors’ routine practice to apply three to four syndesmotic screws in this fashion for patients with neuro-pathic ankle fractures, regardless of whether a syndesmotic injury is initially evident (Fig. 5).

Poor soft tissue envelope is yet another consideration in the patient with diabetes. Age, edema, and autonomic dysregulation can add to already tedious skin quality. In addition to poor baseline tissue, trauma can compound these issues making timing and incision placement a key consideration with surgical intervention. Patients who develop a fracture should be fixated when the soft tissue allows. Patients with absence of skin wrinkling or fracture blisters should have their ankle placed into a splint with underlying multilayer compression or undergo temporary external fixation as deemed necessary by the surgeon. These patients should then be monitored at weekly intervals until soft tissue permits surgical intervention. Further, when placing hardware, a direct lateral incision with a lateral plate application may increase lateral ankle volume to the extent that there is not adequate tissue for closure. Even when closure is possible, the combination of underlying skin pressure from hardware and overlying pressure from a splint or immobilizer may lead to incision necrosis and breakdown (Fig. 6). Therefore, an incision over the posterior border of the fibula or a traditional posterolateral approach may be preferred to allow for better skin mobility and accommodation of hardware. This also has the added benefit of facilitating posterolateral fibula fixation which has been shown in cadaver models to be a stronger construct for supination external rotation fractures than lateral locking plates [27]. This incision placement also allows for a multiple layer closer over hardware.

For patients with a severely compromised soft tissue envelope, including open fractures, there are some alternatives to standard open reduction and internal fixation. These patients have a few options including circular fixation, pin and bar external fixation, percutaneous “closed” intramedullary nails, or primary arthrodesis. The decision as to whether to apply a pin and bar external fixation device versus a circular ring fixator should be considered. In the authors’ experience, the natural life of a pin and bar fixator in the diabetic patient tends to be 4–6 weeks. Beyond this time period, pin loosening, loss of fixation, or pin tract infection is seen. Conversely, Ilizarov-type external fixators are powerful tools that provide fracture stability while decreasing soft tissue insult. These devices are often applied for extended periods of time and are more amenable to fixator maintenance such as wire/pin augmentation, pin swapping, or even the late addition of internal fixation while maintaining placement of the external fixation device. Further, olive wires and tensioning devices and techniques can actually be utilized to aid in fracture reduction [28]. It is the authors’ recommendation that if there is any suspicion that definitive treatment with external fixation may be required, that a ring external fixator be applied at the onset of treatment (Fig. 7).

Fig. 6 An 82-year-old non-insulin-dependent female treated for a trimalleolar ankle fracture with open reduction and internal fixation. Direct lateral plating was utilized and she subsequently developed a non-infected surgical wound with exposed hardware. She was monitored closely off of antibiotics with serial laboratories and imaging.

Fourteen weeks after initial ORIF, with her fracture radiographically healed, she underwent removal of hardware and healed uneventfully by means of secondary intention within 4 weeks. The authors find that this direct lateral approach with direct lateral plating has a particularly high risk of wound development in elderly diabetic patients

Closed nailing is an alternative to traditional internal or external fixation, especially in the elderly who have previously been shown to be at high risk for complications. While there is increasing evidence guiding the treatment of elderly ankle fractures, the literature regarding fractures in elderly patients with diabetes has been somewhat conflicting and more specific research is required. A study by Kong looked at fluoroscopy-guided reduction and fibular nail fixation to manage unstable diabetic ankle fractures. The retrospective review only looked at 24 patients but showed an 8.3% wound infection rate and no amputations [29]. In a cadaveric study by Switaj comparing fibula locked plating and syndesmotic screws with an intramedullary fibula nail, the authors concluded that the two constructs had similar failure characteristics

[30]. This suggests that fibula nailing may be a biomechanically acceptable alternative to locked plating.

Alternatively, trans-articular nailing, either with or without arthrodesis of the ankle, has been described for primary treatment of ankle fractures. Covered in greater detail elsewhere in this issue, this technique poses particular advantages in the most critically ill patients, patients with poor bone and soft tissue, and patients with presumed active Charcot neuroarthropathy (Figs. 8 and 9). This procedure can be successfully accomplished through a variety of approaches (anterior, lateral, medial, or posterior) enabling the surgeon to pick the safest possible interval for the patient. Joint preparation can be performed arthroscopically in high-risk patients or even avoided entirely in the most medically unstable patients.

Fig. 7 A 56-year-old insulin-dependent male with a history of end-stage renal disease on hemodialysis, peripheral neuropathy, retinopathy, and trans-metatarsal amputation for osteomyelitis. The patient underwent initial ORIF with locked plating and subsequently developed a severe deep infection which was treated with explant of hardware and transition to definitive ring external fixation

Fig. 8 A 72-year-old insulin-dependent female with renal insufficiency, peripheral neuropathy, and a history of first ray amputation for osteomyelitis. She presented with a 1-week-old ankle injury and pain with swelling. She was prompted to come to the emergency department when she had spontaneous bleeding from her ankle

This procedure can also be performed quickly or under regional anesthesia which is of particular benefit to elderly and critically ill patients. Data for primary tibiototalcalcaneal arthrodesis in acute diabetic ankle fractures is limited but some data may be drawn from limb salvage literature. In 2018, Lee et al. looked at 20 prospectively gathered patients who underwent TTCA with intramedullary nail for limb salvage purposes including degenerative joint disease, Charcot neuroarthropathy, equinovarus deformity, and non-union of previous pantalar arthrodesis. Of those 20 patients, 35% were diabetic. In a

subgroup analysis, they found wound complication rates and fusion rates to be similar to the primary cohort [31]. Georgiannos and colleagues performed a comparative prospective randomized study among elderly patients with traditional fixation versus trans-articular nailing finding fewer complications in the nailing group ($p < 0.05$) as well as shorter hospital stay while there did not appear to be a more significant functional decline in the nailing group [32••].

Charcot Neuroarthropathy

The incidence and the development of Charcot neuroarthropathy in the setting of ankle fractures remain unclear. While it seems likely that patients with neuropathy and ankle fractures are more likely to develop a Charcot event, more studies are needed to confirm this theory. Characteristics of Charcot may be evident at the time of acute presentation and the surgeon should be careful to identify these. In the setting of neuropathy, unusual comminution, fracture pattern, and bone quality should be cause for concern that the patient is in the midst of an active Charcot event. If acute Charcot in the setting of fracture is suspected, advanced imaging such as CT or MRI may be useful in confirming this. Early recognition of Charcot has been shown to instrumental in preventing the progression of foot and ankle deformity. Chantelau noted that if Charcot was recognized within 1 month of onset, only 1 or 11 patients had progressive deformity. Conversely, of 13 patients with a 3-month delay in diagnosis, 100% had progression of deformity despite immobilization [33]. It is clear that Charcot may develop as a result of acute ankle fractures, but the particular risk factors of development and the incidence of this phenomena are not

Fig. 9 Employing a staged protocol, the patient was treated with a pin and bar external fixator and multiple washouts with closure of her medial wound and delayed primary ankle arthrodesis with intramedullary nail

completely clear. In a matched cohort study by Jones et al., complications of ORIF were compared between patients without diabetes, those with complicated diabetes, and a third group with uncomplicated diabetes. In their study, there was no significant difference in complications with uncomplicated diabetes and the control group. Eight of their patients in the complicated diabetic group went on to develop Charcot, representing 19% of their diabetic study population. Interestingly, they noted four patients were also excluded from the study because they had evidence of Charcot at the time of presentation [19].

Vascular Considerations

One of the more obvious sources of complications surrounding fixation of ankle fractures in patients with diabetes is impaired healing. Certainly, the effects of peripheral arterial disease on ankle fracture outcomes may be devastating, ranging from delayed or non-union, impaired skin healing, infection, and amputation. However, complications surrounding open reduction and internal fixation (ORIF) are not limited to arterial insufficiency. Venous thromboembolism, venous insufficiency, and chronic peripheral edema are all major factors that may influence final outcomes.

As diabetes remains one of the leading non-modifiable causes of peripheral arterial disease and amputation, surgeons will inevitably encounter diabetic patients with ankle fractures and compromised inflow [34]. Interestingly, in a study by Eraso et al., risk factors for peripheral arterial disease (PAD) seem to be additive with patients exhibiting three or more risk factors having more than a 10-fold increase in prevalence of PAD. These factors included hypertension, diabetes, ESRD, smoking, women, and non-Hispanic blacks. While no studies to our knowledge specifically have identified peripheral arterial disease (PAD) in the setting of diabetes as an independent risk factor for complications with ankle fracture surgery, PAD has been found to be a risk factor for complications in foot and ankle surgery independently [9, 35]. With increasing evidence that there is an increased risk of complications with non-operative management of ankle fractures in the setting of diabetes, patients with baseline peripheral arterial disease are likely undergoing ORIF with increasing frequency. Thus, the question as to when to proceed with vascular intervention poses an interesting question. In the instance where the limb or patient are acutely threatened by an unstable deformity or open fracture, the decision to proceed with stabilization first seems clear. However, in patients with more stable yet displaced injuries, it may be prudent to provisionally stabilize the extremity, either by splint or external fixator, and proceed with a vascular intervention or evaluation prior to ORIF. In a very interesting study by Aigner et al., complications of ankle fracture surgery were compared before and after instituting an

algorithm and treatment pathway for peripheral arterial disease. Patients were identified with peripheral arterial disease either by history, pulse exam, or non-invasive vascular testing. In patients with suspected PAD, CT angiogram was performed to confirm the diagnosis. In patients with confirmed PAD, percutaneous intervention was then performed. In their analysis, they showed a decreased rate of complications ($p = 0.021$) in their treatment group after institution of their algorithm [36]. This suggests that, when possible, it may be safe and beneficial to identify and treat PAD prior to fracture intervention. The adequacy of circulation has otherwise been assessed by toe pressure, which may be a safe and convenient study for evaluation of healing potential in the setting of an ankle fracture. This study obviates the need for cuff placement on an ankle that may otherwise be unstable or painful. Great toe pressure has been found to be at least 78% sensitive in detecting significant peripheral arterial disease and a toe pressure of greater than 47 mmHg has been found to have a greater predictive value for healing than arterial duplex [37, 38].

Though the manifestations of PAD may seem more glaring, the implications of venous disease may be equally serious in the management of these fractures. Whether because of venous thromboembolism (VTE) or simply venous insufficiency, venous and coagulopathic complications of ankle surgery in these patients can be serious.

Venous insufficiency and its manifestations pose potentially modifiable or preventable complications with these patients. Venous leg ulceration, in isolation, is a risk factor for infection and loss of limb. These ulcerations may be caused by trauma, exacerbated by traumatic edema, or present obstacles for surgical exposure. Patients with venous reflux or venous insufficiency may have particularly poor skin quality around the malleoli, potentially increasing the risk of perioperative wound healing complications if certain surgical intervals are employed. A surgeon should be well versed in alternative approaches for fracture reduction and fixation to avoid these high-risk areas as necessary. It has been our approach in these patients, when possible, to apply a multilayer compression bandage for 7–10 days prior to surgery to limit the complications of venous insufficiency. The use of Unna boots has been particularly helpful, serving to moisturize the skin and achieve dramatic reduction in edema pre-operatively.

One of the more highly debated topics in foot and ankle surgery is the necessity for routine thromboprophylaxis for VTE. The overall incidence of VTE in foot and ankle surgery is generally accepted to be low, ~1% or lower [39]. The most recent CHEST guidelines do not recommend routine prophylaxis for VTE with foot and ankle surgery. Interestingly though, a 2007 survey by Gadgil et al. found only 19% of foot and ankle surgeons utilized routine prophylaxis [40]. However, a recent surgeon survey found that 98% of foot and ankle surgeons do prophylax patients they consider to be high risk for VTE [40]. Research is somewhat conflicted

regarding the effect of diabetes on increased incidence of VTE with ankle fractures. Basques et al. found only that BMI, heart disease, and dependent functional status were independent risk factors for VTE after ankle fracture whereas Yi et al. found that diabetes was associated with an increased risk of VTE in patients scanned prior to surgery [41, 42]. What seems clearer is that patients with diabetes seem to be at an overall increased risk for VTE with one study recognizing a 1.4-fold increase in hazard ratio in their diabetic population and an increased risk for VTE in the setting of orthopedic surgery, such as knee replacement [43]. Thus, the consensus remains that thromboprophylaxis for diabetic patients considered to be high risk should be considered, but routine prophylaxis has not been recommended.

Patient Optimization

It is important to recognize the modifiable and semi-modifiable risk factors of patients with diabetes. It is well recognized that diabetes and its associated conditions have far reaching effects on patients, with end-organ implications such as infection, impaired bone healing, VTE, nephropathy, and Charcot neuroarthropathy. While many factors, such as the presence of diabetes, age, and pre-existing neuropathy, are not modifiable, there are potentially modifiable factors which may influence outcomes in these patients.

Glycemic Control

Hemoglobin A1c has been the benchmark by which overall diabetic control has been measured. There have been a wealth of studies illustrating the numerous health risks of having an elevated A1c, particularly related to perioperative risks. Research to date has concentrated on the effect of pre-operative A1c on overall outcomes. In evaluating elective arthrodesis and non-elective fracture surgery patients, Shibuya et al. concluded that there was significantly elevated risk of bone healing complications in patients with an A1c > 7% [44]. Similarly, Liu and colleagues found that there was statistically significant correlation between increased A1c and increased likelihood of poor radiographic and functional outcomes after ankle fractures. In their study, they found that complication rates among diabetic ankle fractures were generally high but that an A1c of greater than 6.5% correlated with especially poor results [45]. A particularly interesting study by Lee et al. actually evaluated the effect of ankle ORIF on glycemic control after surgery. Patients had pre-operative fasting blood glucose and A1c evaluations and then were followed post-operatively for glycemic control. Patients undergoing ankle ORIF were found to have an increase in mean fasting blood glucose at 1 month after surgery and then appeared to have a study decline of 2.2 mg/dL per month thereafter [46]. This

underscores the effect that the overall change in functional status has on these patients and should prompt surgeons to pay special attention to modifiable factors post-operatively.

Malnutrition

With an increased rate of surgical site infection and delayed skin and bone healing, considerable attention should also be paid to the patient's nutritional status. Pre-albumin and albumin are the most commonly utilized markers for patient's nutritional status. Protein deprivation has been shown in numerous models to result in impaired bone healing. Obese and morbidly obese patients have also been found to be statistically more likely to have hypoalbuminemia [47]. Hypoalbuminemia has been shown to be detrimental to healing a variety of lower extremity surgeries [48–50]. Particularly, hypoalbuminemia has revealed a poor prognosis for geriatric hip fracture patients, having a statistically significant increased mortality. While a direct comparison cannot be drawn, a high proportion of elderly patients are likely to have diabetes and may be comparably frail. Low albumin has also been shown to be associated with lower likelihood of wound healing of the lower extremities [51]. Pre-albumin has been shown overall to be a more accurate marker for nutritional status. Studies have shown a correlation between low pre-albumin and surgical site infection in spine surgery [52, 53]. There is conflicting evidence as to the effectiveness of application of vancomycin powder to foot and ankle surgical sites. Wukich et al. showed a significant decrease in surgical site infection with use of intrawound vancomycin powder in a diabetic population while Singh et al. did not observe a significant decrease in infection rate in periarticular tibia fractures with the use of vancomycin powder [54, 55]. Thus, more studies are needed to evaluate the efficacy of vancomycin powder as a tool in the management of diabetic ankle fractures.

Vitamin D

Management of vitamin D levels may also play a significant role in the outcomes of patients with diabetes and ankle fractures. Both end-stage renal disease and obesity have known associations with hypovitaminosis D. As obesity and chronic kidney disease are both common among diabetic patients, this population seems to be particularly at risk. In a study evaluating the prevalence of hypovitaminosis D in foot and ankle trauma patients, vitamin D levels of patients with fractures were compared to a second cohort with ankle sprains. The authors found that those patients with foot or ankle fractures had a statistically significantly increased likelihood to have low vitamin D compared to patients with an ankle sprain ($p = 0.02$) [56]. Looking specifically at ankle fractures, Warner et al. showed a trend toward

decreased functional outcomes in ankle fracture patients with hypovitaminosis D; however, their study did not find a significant difference in complication rates with patients who had adequate vitamin D [57].

Conclusion

While many articles discuss the perils of diabetic ankle fracture management, there is little definitive evidence on the optimal treatment for these injuries. These patients are highly complicated and present multifaceted challenges for surgeons. One must consider all comorbidities and adjust accordingly. Continued research is required to identify which patients are at risk for specific complications so more robust recommendations can be achieved. The literature does indicate that operative intervention for unstable fracture patterns in the diabetic and elderly populations is beneficial and has lower rates of complications. Care should be taken to ensure that these patients are optimized throughout the perioperative period.

Compliance with Ethical Standards

Conflict of Interest All authors declare no conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:

- Of importance
- Of major Importance

1. Daly PJ, Fitzgerald RH, Joseph Melton L, Ilstrup DM. Epidemiology of ankle fractures in Rochester, Minnesota. *Acta Orthop Scand*. 2009;58(5):539–44. <https://doi.org/10.3109/17453678709146395>.
2. Statistics About Diabetes. (2017). Retrieved March 10, 2018, from <http://www.diabetes.org/diabetes-basics/statistics/>.
3. Regan DK, Manoli AI, Hutzler L, Konda SR, Egol KA. Impact of diabetes mellitus on surgical quality measures after ankle fracture surgery: Implications for a value-based compensation and a pay for performance. *J Orthop Trauma*. 2015;29(12):e483–e6. <https://doi.org/10.1097/BOT.0000000000000920>.
4. Lanzetti RM, Lupariello D, Venditto T, Guzzini M, Ponzio A, de Carli A, et al. The role of diabetes mellitus and BMI in the surgical treatment of ankle fractures. *Diabetes Metab Res Rev*. 2018;34:e2954. <https://doi.org/10.1002/dmrr.2954>.
5. Pincus D, Veljkovic A, Zochowski T, Mahomed N, Ogilvie-Harris D, Wasserstein D. Rate of and risk factors for intermediate-term reoperation after ankle fracture fixation: a population-based cohort study. *J Orthop Trauma*. 2017;31(10):e315–20. <https://doi.org/10.1097/BOT.0000000000000920>. This study illustrates the unexpectedly high incidence of re-operation after ankle ORIF. Most importantly, a more significant portion of re-operation in diabetic patients is secondary to infection.
6. Kumar A, Mishra P, Tandon A, Arora R, Chadha M. Effect of CT on management plan in malleolar ankle fractures. *Foot Ankle Int*. 2018;39(1):59–66. <https://doi.org/10.1177/1071100717732746>. This study suggests that X-ray alone may not be adequate for evaluation of malleolar ankle fractures.
7. Fateh HR, Madani SP, Heshmat R, Larijani B. Correlation of Michigan neuropathy screening instrument, United Kingdom screening test and electrodiagnosis for early detection of diabetic peripheral neuropathy. *J Diabetes Metab Disord*. 2016;15:8. <https://doi.org/10.1186/s40200-016-0229-7>. eCollection 2015.
8. Lovy AJ, Dowdell J, Keswani A, Koehler S, Kim J, Weinfeld S, et al. Nonoperative versus operative treatment of displaced ankle fractures in diabetics. *Foot Ankle Int*. 2017;38(3):255–60. <https://doi.org/10.1177/1071100716678796>. This study suggests that non-operative management of displaced ankle fractures in diabetic patients is not recommended. Complication rates were actually lower in the operative group.
9. Schade MA, Hollenbeak CS. Early postoperative infection following open reduction internal fixation repair of closed malleolar fractures. *Foot Ankle Spec*. 2017; <https://doi.org/10.1177/1938640017735887>.
10. Thangarajah T, Prasad PS, Narayan B. Surgical site infections following open reduction and internal fixation of ankle fractures. *Open Orthop J*. 2009;3:56–60.
11. SooHoo NF, Krenke L, Eagan MJ, Gurbani B, Ko CY, Zingmond DS. Complication rates following open reduction and internal fixation of ankle fractures. *J Bone Joint Surg Am*. 2009;91:1042–9.
12. Korim MT, Payne R, Bhatia M. A case control study of surgical site infection following operative fixation of fractures of the ankle in a large U.K. trauma unit. *Bone Joint J*. 2014;96:636–40.
13. Ovaska MT, Makinen TJ, Madanat R, et al. Risk factors for deep surgical site infection following operative treatment of ankle fractures. *J Bone Joint Surg Am*. 2013;95:348–53.
14. Miller AG, Margules A, Raikin SM. Risk factors for wound complications after ankle fracture surgery. *J Bone Joint Surg Am*. 2012;94:2047–52.
15. Haddix KP, Clement RC 3rd, Tennant JN, Ostrum RF. Complications following operatively treated ankle fractures in insulin- and non-insulin-dependent diabetic patients. *Foot Ankle Spec*. 2017;11:206–16. <https://doi.org/10.1177/1938640017714867>.
16. Wukich DK, Kline AJ. The management of ankle fractures in patients with diabetes. *J Bone Joint Surg Br*. 2008;90:1570–8.
17. Bibbo C, Lin SS, Beam HA, Behrens FF. Complications of ankle fractures in diabetic patients. *Orthop Clin N Am*. 2001;32:113–33.
18. Blotter RH, Connolly E, Wasan A, Chapman MW. Acute complications in the operative treatment of isolated ankle fractures in patients with diabetes mellitus. *Foot Ankle Int*. 1999;20:687–94.
19. Jones KB, Maiers-Yelden KA, Marsh JL, Zimmerman MB, Estlin M, Saltzman CL. Ankle fractures in patients with diabetes mellitus. *J Bone Joint Surg Br*. 2005;87:489–95.
20. Costigan W, Thordarson DB, Debnath UK. Operative management of ankle fractures in patients with diabetes mellitus. *Foot Ankle Int*. 2007;28:32–7.
21. Kristiansen B. Results of surgical treatment of malleolar fractures in patients with diabetes mellitus. *Dan Med Bull*. 1983;30:272–4.
22. McCormack RG, Leith JM. Ankle fractures in diabetics: complications of surgical management. *J Bone Joint Surg Br*. 1998;80:689–92.
23. Flynn JM, Rodriguez-del Rio F, Piza PA. Closed ankle fractures in the diabetic patient. *Foot Ankle Int*. 2000;21:311–9.

24. Bazarov I, Peace RA, Lagaay PM, Patel SB, Lyon LL, Schuberth JM. Early protected weightbearing after ankle fractures in patients with diabetes mellitus. *J Foot Ankle Surg.* 2017;56(1):30–3. <https://doi.org/10.1053/j.jfas.2016.09.010>.
25. Sammarco VJ. Superconstructs in the treatment of Charcot foot deformity: plantar plating, locked plating, and axial screw fixation. *Foot Ankle Clin.* 2009 Sep;14(3):393–407. <https://doi.org/10.1016/j.fcl.2009.04.004>.
26. Perry MD, Taranow WS, Manoli A 2nd, Carr JB. Salvage of failed neuropathic ankle fractures: use of large-fragment fibular plating and multiple syndesmotic screws. *J Surg Orthop Adv.* 2005;14(2):85–91.
27. Minihiene KP, Lee CH, Ahn C, Zhang LQ, Merk BR. Comparison of lateral locking plate and antiglide plate for fixation of distal fibular fractures in osteoporotic bone: a biomechanical study. *J Orthop Trauma.* 2006;20:526–66.
28. Kapoor SK, Kataria H, Patra SR, Boruah T. Capsuloligamentotaxis and definitive fixation by an ankle-spanning Ilizarov fixator in high-energy pilon fractures. *J Bone Joint Surg Br.* 2010 Aug;92(8):1100–6. <https://doi.org/10.1302/0301-620X.92B8.23602>.
29. Ashman BD, Kong C, Wing KJ, Penner MJ, Bugler KE, White TO, et al. Fluoroscopy-guided reduction and fibular nail fixation to manage unstable ankle fractures in patients with diabetes: a retrospective cohort study. *Bone Joint J.* 2016;98-B(9):1197–201. <https://doi.org/10.1302/0301-620X.98B9.37140>.
30. Switaj PJ, Fuchs D, Alshouli M, Patwardhan AG, Voronov LI, Muriuki M, et al. A biomechanical comparison study of a modern fibular nail and distal fibular locking plate in AO/OTA 44C2 ankle fractures. *J Orthop Surg Res.* 2016;11(1):100. <https://doi.org/10.1186/s13018-016-0435-5>.
31. Lee BH, Fang C, Kunnasegaran R, Thevendran G. Tibiototalcalcaneal arthrodesis with the hindfoot arthrodesis nail: a prospective consecutive series from a single institution. *J Foot Ankle Surg.* 2018;57(1):23–30. <https://doi.org/10.1053/j.fas.2017.05.041>.
32. Georgiannos D, Lampridis V, Bisbinas I. Fragility fractures of the ankle in the elderly: open reduction and internal fixation versus tibio-talo-calcaneal nailing: short-term results of a prospective randomized-controlled study. *Injury.* 2017;48(2):519–24. <https://doi.org/10.1016/j.injury.2016.11.017>. **Management of displaced elderly ankle fractures may be better suited to intramedullary nailing given equal functional and reduced complications. It is important to consider intramedullary nailing for high-risk patients with ankle fractures.**
33. Chantelau E. The perils of procrastination: effects of early vs. delayed detection and treatment of incipient Charcot fracture. *Diabet Med.* 2005 Dec;22(12):1707–12.
34. Eraso LH, Fukaya E, Mohler ER 3rd, Xie D, Sha D, Berger JS. Peripheral arterial disease, prevalence and cumulative risk factor profile analysis. *Eur J Prev Cardiol.* 2014;21(6):704–11. <https://doi.org/10.1177/2047487312452968>.
35. Sun Y, Wang H, Tang Y, Zhao H, Qin S, Xu L, et al. Incidence and risk factors for surgical site infection after open reduction and internal fixation of ankle fracture: a retrospective multicenter study. *Medicine (Baltimore).* 2018;97(7):e9901. <https://doi.org/10.1097/MD.00000000000009901>.
36. Aigner R, Lechler P, Boese CK, Bockmann B, Ruchholtz S, Frink M. Standardised pre-operative diagnostics and treatment of peripheral arterial disease reduce wound complications in geriatric ankle fractures. *Int Orthop.* 2018;42(2):395–400. <https://doi.org/10.1007/s00264-017-3705-x>. **It is important to recognize peripheral arterial disease and its influence on outcomes of ankle fractures. This study shows that in select patients, it may be safe to proceed with pre-emptive vascular intervention and subsequent ORIF, rather than primarily with ORIF.**
37. Tehan PE, Barwick AL, Sebastian M, Chuter VH. Diagnostic accuracy of resting systolic toe pressure for diagnosis of peripheral arterial disease in people with and without diabetes: a cross-sectional retrospective case-control study. *J Foot Ankle Res.* 2017;10(58):58. <https://doi.org/10.1186/s13047-017-0236-z>.
38. Stone PA, Glomski A, Thompson SN, Adams E. Toe pressures are superior to duplex parameters in predicting wound healing following toe and foot amputations. *Ann Vasc Surg.* 2018;46:147–54. <https://doi.org/10.1016/j.avsg.2017.08.012>.
39. Shibuya N, Frost CH, Campbell JD, Davis ML, Jupiter DC. Incidence of acute deep vein thrombosis and pulmonary embolism in foot and ankle trauma: analysis of the National Trauma Data Bank. *J Foot Ankle Surg.* 2012;51(1):63–8. <https://doi.org/10.1053/j.jfas.2011.10.017>.
40. Weisman MHS, Holmes JR, Irwin TA, Talusan PG. Venous thromboembolic prophylaxis in foot and ankle surgery: a review of current literature and practice. *Foot Ankle Spec.* 2017 Aug;10(4):343–51. <https://doi.org/10.1177/1938640017692417>.
41. Basques BA, Miller CP, Golinvaux NS, Bohl DD, Grauer JN. Risk factors for thromboembolic events after surgery for ankle fractures. *Am J Orthop (Belle Mead NJ).* 2015;44(7):E220–4.
42. Yi X, Zhu J, Wei M, Li J, Chen J, Wang Y, et al. Risk factors of venous thrombosis in patients with ankle fractures. *Int Angiol.* 2014;33(4):324–8.
43. Yang G, Meng F, Liu Y, Kong L, Shen Y. Diabetes mellitus and risk of deep vein thrombosis after total knee replacement: a meta-analysis of cohort studies. *Int J Clin Exp Med.* 2015;8(6):9086–92. eCollection 2015.
44. Shibuya N, Humphers JM, Fluhman BL, Jupiter DC. Factors associated with nonunion, delayed union, and malunion in foot and ankle surgery in diabetic patients. *J Foot Ankle Surg.* 2013;52(2):207–11. <https://doi.org/10.1053/j.jfas.2012.11.012>.
45. Liu J, Ludwig T, Ebraheim NA. Effect of the blood HbA1c level on surgical treatment outcomes of diabetics with ankle fractures. *Orthop Surg.* 2013 Aug;5(3):203–8. <https://doi.org/10.1111/os.12047>.
46. Lee SY, Park MS, Kwon SS, Sung KH, Jung HS, Lee KM. Influence of ankle fracture surgery on glycemic control in patients with diabetes. *BMC Musculoskelet Disord.* 2016;17:137. <https://doi.org/10.1186/s12891-016-0987-x>.
47. Mosli RH, Mosli HH. Obesity and morbid obesity associated with higher odds of hypoalbuminemia in adults without liver disease or renal failure. *Diabetes Metab Syndr Obes.* 2017;10:467–72. <https://doi.org/10.2147/DMSO.S149832>. eCollection 2017.
48. Morisaki K, Yamaoka T, Iwasa K. Risk factors for wound complications and 30-day mortality after major lower limb amputations in patients with peripheral arterial disease. *Vascular.* 2018;26(1):12–7. <https://doi.org/10.1177/1708538117714197>.
49. Peacock MR, Farber A, Eslami MH, Kalish JA, Rybin D, Doros G, et al. Hypoalbuminemia predicts perioperative morbidity and mortality after infrainguinal lower extremity bypass for critical limb ischemia. *Ann Vasc Surg.* 2017;41:169–175.e4. <https://doi.org/10.1016/j.avsg.2016.08.043>.
50. Bohl DD, Shen MR, Hannon CP, Fillingham YA, Darrih B, Della Valle CJ. Serum albumin predicts survival and postoperative course following surgery for geriatric hip fracture. *J Bone Joint Surg Am.* 2017;99(24):2110–8. <https://doi.org/10.2106/JBJS.16.01620>.
51. Legendre C, Debure C, Meaume S, Lok C, Golmard JL, Senet P. Impact of protein deficiency on venous ulcer healing. *J Vasc Surg.* 2008;48(3):688–93. <https://doi.org/10.1016/j.jvs.2008.04.012>.
52. Kudo D, Miyakoshi N, Hongo M, Kasukawa Y, Ishikawa Y, Mizutani T, et al. Relationship between preoperative serum rapid turnover proteins and early-stage surgical wound infection after

- spine surgery. *Eur Spine J.* 2017;26(12):3156–61. <https://doi.org/10.1007/s00586-016-4855-z>.
53. Tempel Z, Grandhi R, Maserati M, Panczykowski D, Ochoa J, Russavage J, et al. Prealbumin as a serum biomarker of impaired perioperative nutritional status and risk for surgical site infection after spine surgery. *J Neurol Surg A Cent Eur Neurosurg.* 2015;76(2):139–43. <https://doi.org/10.1055/s-0034-1394188>.
 54. Wukich DK, Dikis JW, Monaco SJ, Strannigan K, Suder NC, Rosario BL. Topically applied vancomycin powder reduces the rate of surgical site infection in diabetic patients undergoing foot and ankle surgery. *Foot Ankle Int.* 2015;36(9):1017–24. <https://doi.org/10.1177/1071100715586567>.
 55. Singh K, Bauer JM, GY LC, Bible JE, Mir HR. Surgical site infection in high-energy peri-articular tibia fractures with intra-wound vancomycin powder: a retrospective pilot study. *J Orthop Traumatol.* 2015;16(4):287–91. <https://doi.org/10.1007/s10195-015-0352-0>.
 56. Smith JT, Halim K, Palms DA, Okike K, Bluman EM, Chiodo CP. Prevalence of vitamin D deficiency in patients with foot and ankle injuries. *Foot Ankle Int.* 2014;35(1):8–13. <https://doi.org/10.1177/1071100713509240>.
 57. Warner SJ, Garner MR, Nguyen JT, Lorch DG. Perioperative vitamin D levels correlate with clinical outcomes after ankle fracture fixation. *Arch Orthop Trauma Surg.* 2016 Mar;136(3):339–44. <https://doi.org/10.1007/s00402-015-2376-6>.