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Ankle fractures in diabetic patients

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- Surgical complications are more common in patients with complicated diabetes (presence of inner organ failure, neuropathy).

- Of all patients undergoing ankle fracture fixation, approximately 13% are diabetic and 2% have complicated diabetes mellitus.

- Non-operative management of ankle fractures in patients with complicated diabetes results in an even higher rate of complications.

- Insufficient stability of ankle fractures (treated operatively, or non-operatively) can trigger Charcot neuroarthropathy, and result in bone loss, deformity, ulceration, and the need for amputation.

- Rigid fixation is recommended. Hindfoot arthrodesis (as primary procedure or after failed ankle fracture management) can salvage the limb in approximately 80% of patients.

- Early protected weight bearing can be allowed, provided rigid fixation without deformity has been achieved.

Keywords: ankle fractures; diabetic; fixation

Introduction

Approximately one in eight patients undergoing surgical treatment for rotational ankle fracture is diabetic.[1,2] Complications after ankle fracture fixation in diabetics have been shown to vary between 26% and 47% versus approximately 15% in matched control groups of non-diabetic patients.[1,3–5] A recent large-scale study showed that diabetes mellitus (DM) had the highest odds for amputation after ankle fracture fixation, compared to any other risk factors,[6] Diabetics are also more likely to undergo secondary operations[1,6] and have worse outcomes regarding activity limitation scores.[1] Because of the higher risk of infection and other serious surgical complications, non-operative management of acute ankle fractures in diabetics, had been considered by some, in the past, as a safer option.[7] More recent evidence, however, shows that this 'conservative' approach may actually result in higher complication rates and more severe, catastrophic complications,[8] as an ankle injury can trigger the process of Charcot neuroarthropathy which causes joint destruction, bone loss, and deformity.[9]

The present article emphasizes on the need for operative rigid fixation of rotational ankle fractures in diabetic patients, taking into consideration the pathophysiology associated with diabetes, and recent literature regarding treatment outcomes. It identifies risk factors associated with complications, also providing a rationale and recommendations regarding preoperative assessment and management of ankle fractures in diabetic patients.

'Complicated' diabetes mellitus

Given that poor glycaemic control causes damage to the organs of the human body, a distinction between 'complicated' (in the presence of peripheral neuropathy, peripheral arterial disease, internal organ disease), versus 'uncomplicated' diabetes, needs to be made. DM, characterized by hyperglycaemia, is a metabolic disorder with a wide range of clinical manifestations, depending on the degree to which the organs of the human body have been affected by the increased intracellular production of abnormal metabolic substances. This intracellular destruction results from non-enzymatic glycosylation of proteins, because of the increased glucose levels in the bloodstream.[10] Thus, any human organ can be affected as a result of chronic poor glycaemic control. Common problems that diabetics develop are: peripheral neuropathy, macro- and micro-vascular disease, reduced immune system response, kidney disease, retinopathy etc.[10] The presence of peripheral neuropathy in diabetics provides evidence of damage to tissues and organs, and is, thus, indication of chronic

suboptimal glycaemic control.[11] All the above conditions constitute what we define as 'complicated DM'.

Data analysis of a large cohort of 58,748 patients undergoing ankle fracture fixation in New York revealed that 12.5% were diabetic, whilst 14.6% of diabetics (1.9% of all patients with ankle fractures), had complicated DM.[2]

Assessment of diabetic patients with ankle fractures

The diabetic patient with an injured limb presents a challenge to the orthopaedic surgeon. It is essential to detect 'high-risk' patients, not only in order to plan surgical treatment appropriately, but also to allow preoperative counselling in order to obtain consent for treatment.

Hyperglycaemia plays a central role in the pathogenesis of complications,[10] as we discussed earlier, and measurement of HbA1c may provide a valid and easily available tool to diagnose the degree to which the human body has been affected by diabetes. It has been shown that values of HbA1c > 7%, are associated with increased complication rates following orthopaedic surgery, and has been used as a 'cut off' point over which elective surgery should be avoided.[12]

Standard clinical examination to detect diabetic peripheral neuropathy (e.g. peripheral sensation examination using the Semmes Weinstein monofilament examination),[13] may be impractical and unreliable in patients who have sustained an acute ankle fracture. First, the test would have to be performed before a plaster back slab or other form of immobilization had been applied, or the immobilization device should be removed to free the plantar aspect of the foot, and this may not be appropriate in an unstable fracture. Furthermore, foot swelling and pain, as well as the patient's distress may influence the examination findings. There are no reports in the literature regarding accuracy of clinical testing for peripheral neuropathy in diabetic patients with acute ankle fractures, and in the authors' experience this would be impractical and unreliable for reasons stated before. Thus, one may have to rely on patients' medical history (if available) and on investigations (e.g. blood tests) that reveal the diagnosis of complicated DM (in presence of inner organ dysfunction), or poorly controlled DM (if HbA1C > 7%).

A multi-disciplinary team approach is often required, in order to diagnose potential complications and to efficiently manage the patient with complicated diabetes and an ankle fracture. [9,10] Diabetic patients need to be actively examined for peripheral artery occlusion. In the patient with a painful and swollen ankle following acute fracture, it may be difficult or impossible to assess dorsalis pedis or posterior tibial artery pulses, and to measure the ankle-brachial index (ABI) (ratio of systolic blood pressure

above the ankle to that in the brachial artery). An ABI ratio of < 0.9 suggests peripheral vascular disease. On the other hand, it should be possible to measure transcutaneous oxygen pressure (TcPO2), as values less than 30 mm Hg indicate limb ischemia, and revascularization prior to definite fracture fixation may be required.[10]

Physician input is also necessary and sometimes a vascular surgeon's input is mandatory if peripheral macroangiopathy is suspected.[9,10] Although no evidence-based recommendations can be made, due to absence of relevant reports in the literature, in the presence of significant peripheral artery occlusion, revascularization may be required prior to definite ankle fracture fixation.

Charcot neuroarthropathy and ankle fractures

Trauma can elicit the onset of Charcot neuroarthropathy in diabetics, the pathophysiological mechanisms of which are not fully understood. In brief, pre-existing neuropathy and trauma can cause rapid 'softening' of bone (osteopenia) and cartilage degeneration, and/or can initiate a neuroinflammatory response resulting in joint collapse and deformity.[10] The latter can result in catastrophic complications and – following a pathway of lower leg and foot deformation, ulceration, and deep infection – can lead to amputation. This might occur both after non-operative management of ankle fractures (Fig. 1), and also after failure of operative fixation (Fig. 2 a and b). In both scenarios,

Fig. 1 Charcot neuroarthropathy of the ankle after non-operative management of an unstable ankle fracture.
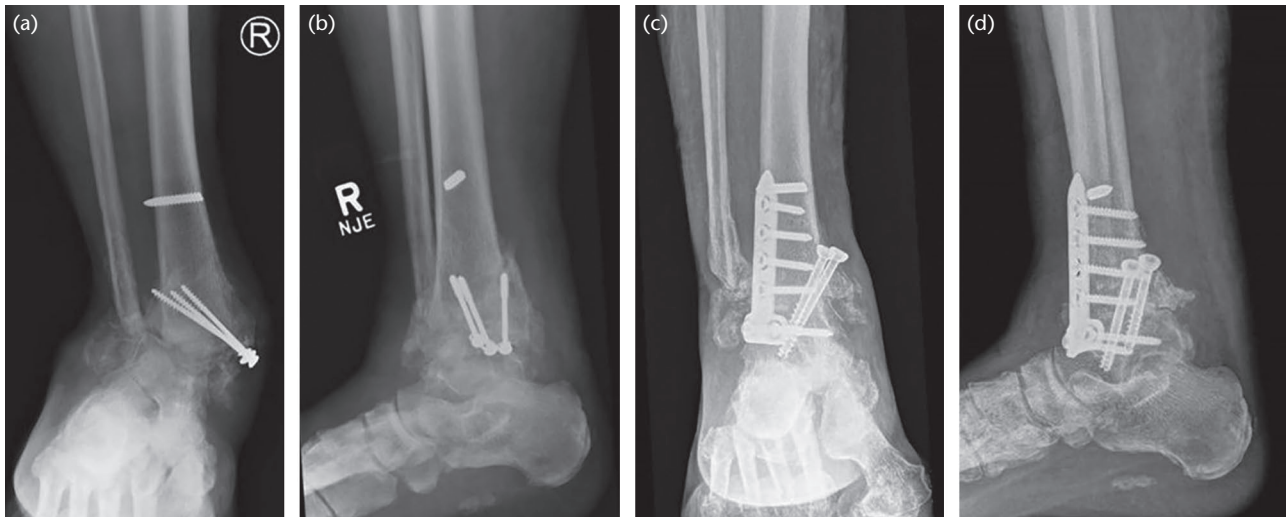
Fig. 2 Unstable fracture in a 70-year-old diabetic patient, treated initially with external fixation and 'minimal' internal fixation (a, b), complicated by joint destruction due to Charcot neuroarthropathy, without signs of infection. It was salvaged with ankle arthrodesis using a rigid fixation construct (plate with locking screws, augmented by tibiotalar compression screws) (c, d).

Fig. 3 A 65-year-old alcohol-dependent, psychotic, insulin-dependent diabetic male patient, with chronic renal failure, had sustained ankle and foot injury nine months before. 'Minimal' percutaneous fixation was applied to the midfoot, whilst the ankle injury was treated non-operatively. Charcot neuroarthropathy of ankle and midfoot (a, b), resulted in gross deformity (c) and ulceration (d). A below-knee amputation was required (e, f).

it seems that inadequate ankle fracture stabilization resulted in Charcot arthropathy and joint destruction.

Patients lose protective sensation and are at higher risk of ulceration. At the same time they are at risk of developing Charcot neuroarthropathy, which can be a result of repetitive micro-trauma. This, combined with lack of protective sensation and pain, can lead to abnormal load and give onset to a neuroinflammatory process that will cause bone resorption, osteopenia, cartilage degeneration, joint collapse and foot deformity. Foot and ankle deformity in the absence of normal sensation can lead to ulceration, deep infection, potential amputation (Fig. 3) and even death. The onset of neuroarthropathy can also be a consequence of more significant trauma that causes a fracture. Inadequate immobilization can initiate the Charcot neuroarthropathy process, even if the diabetic patient had no Charcot joints prior to the traumatic event. Thus, either repetitive micro-trauma, or
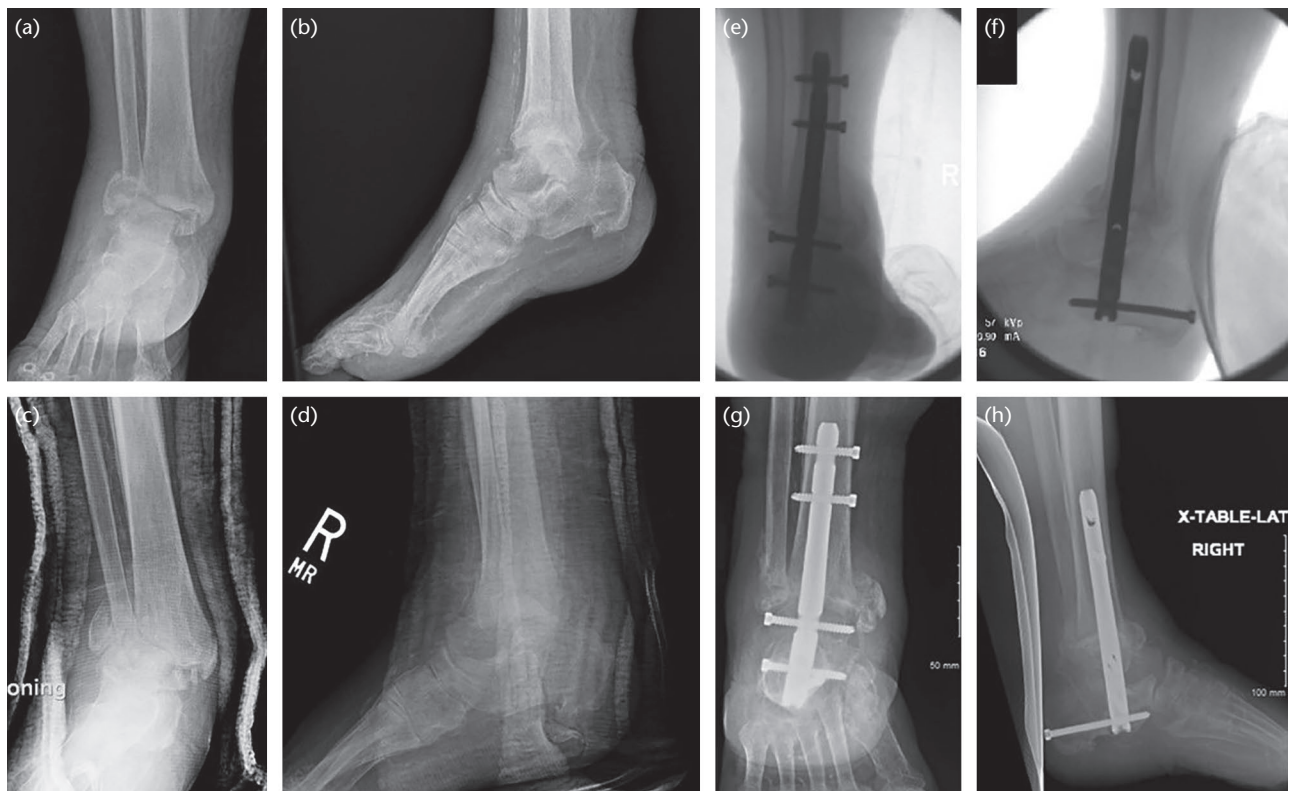
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Fig. 4 A 70-year-old female patient, with diabetic neuropathy and limited mobility, on haemodialysis for chronic renal failure, sustained a bimalleolar fracture (a, b). Due to her poor general health and ankle swelling her surgery was postponed for two weeks, and she developed Charcot neuroarthropathy (c, d). Tibio-talo-calcaneal arthrodesis using retrograde hindfoot nail was performed (e, f) in order to salvage the limb. Arthrodesis, in good alignment, showed signs of union already at six weeks (g, h).

a significant acute traumatic event (e.g. causing ligamentous injury – 'sprain' – or fracture) can result in Charcot neuroarthropathy. Trauma and neuroarthropathy of the midfoot can cause flatfoot deformity that can be salvaged even without surgery, if a total contact cast is applied in the early stages. The foot will become flat, but can remain functional.[10]

An ankle fracture, though, may be more difficult to manage non-operatively. A possible explanation is that the ankle represents a 'hinge' between the foot and the rest of the body, and the forces acting at the ankle joint are large. Therefore, in the neuropathic foot, lacking protective sensation, standard below-knee cast immobilization may still allow significant movement at the fracture site and initiate the Charcot neuroarthropathy process.

Risk factors associated with ankle fractures in diabetics

It is known that the postoperative infection rate in patients undergoing foot and ankle surgery is higher in diabetics. Wukich et al analysed the outcomes of 1000 patients undergoing foot and ankle surgery and found a surgical site infection rate of 13.2% in diabetics, compared to 2.8% in non-diabetics.[14] Another study revealed a similar (12%) infection rate in 84 diabetic patients undergoing ankle fracture fixation, whilst the overall complication rate was 14%.[15] Schmidt et al analysed outcomes of a large cohort (979 patients) who underwent surgical treatment for their ankle fractures. Diabetics (131 patients, 13.4%) experienced more complications (26.0% versus 14.6%, p = 0.001). Deep infections were also more common in diabetics (6.9% versus 1.3%, p = 0.001), who also underwent more unplanned procedures, including debridement, arthrodesis, and amputation (18.3% versus 9.1%, p = 0.001). Diabetes was a significant independent predictor of worse Foot Function Index activity limitation scores (p = 0.03), whilst subscores for pain and dysfunction were not worse in diabetics, possibly due to their reduced peripheral sensation and low functional demands. The authors did not make a distinction between patients with complicated and uncomplicated DM.[1]

Level I evidence in a large cohort of 2060 patients undergoing foot and ankle surgery, has shown surgical site infections to be independently associated with peripheral neuropathy and HbA1C > 8%.[11] Interestingly,

non-diabetic patients with neuropathy undergoing foot and ankle surgery are at higher risk for developing infection, whilst patients with uncomplicated DM were found not to have higher risk for infection, compared to non-diabetic patients without neuropathy.[11] The same study showed that complicated DM was more often associated with insulin-dependent diabetes mellitus (IDDM).[11]

A Canadian study analysed data from more than 45,000 patients (general population), and found that odds for amputation was highest in diabetics (odds ratio [OR], 7.42; 95% confidence interval [CI], 3.73–14.86; p < 0.001).[6] However, we have to bear in mind that non-operative management of ankle fractures in diabetic patients can result in an even higher complication rate. Lovy et al showed a 21-fold odds ratio for complications if ankle fractures were managed non-operatively.[8] They also found that the complication rate for secondary surgical fixation after failed initial non-operative management was 100% vs. 12.5% for primary open reduction and internal fixation (p = .005).[8] In conclusion, diabetic patients are considered as higher risk for complications after sustaining ankle fractures, and the risk is higher if managed non-operatively.

Severity of neuropathy is directly related to poor glycaemic control and chronicity of disease. A 1% reduction in HbA1C results in a 25–30% reduction in the rate of complications,[16] whilst an HbA1C value greater than 6.5 mg/dl in diabetic patients sustaining ankle fractures has been correlated with worse radiological and clinical outcomes.[12]

Wukich et al[14] also examined the effect of lower leg neuropathy and other complications (e.g. kidney disease, vascular disease) associated with diabetes mellitus, in patients undergoing foot and ankle surgery, and found that the complication rate in patients without neuropathy or other organ failure, was not different compared to that of non-diabetics.[14]

Analysis of a cohort of diabetic patients comparing 46 with complicated diabetes (organ failure, or neuropathy) and 59 with uncomplicated diabetes, revealed a 3.8-fold increase in complications and 5-fold increase in the need for revision surgery in patients with complicated DM.[4] Similarly, SooHoo et al, reviewing a database of more than 57,000 ankle fracture surgeries performed in Los Angeles, CA (United States of America), found that complicated DM was a strong predictor for complications (OR, 2.30; p < 0.001), as was peripheral vascular disease (OR, 1.65; p < 0.001).[17]

Others had also shown neuropathy, absence of pedal pulses and hypertension to be associated with surgical complications in 11 out of 12 (92%) patients with complicated DM undergoing operative ankle fracture management, whilst IDDM had no effect on the complication rate in this small group of patients.[15] A larger-scale study (reviewing records of 4412 patients [general population] undergoing ankle fracture open reduction and internal fixation), however, revealed IDDM to have the highest odds ratio (compared to any other parameter tested) for any adverse event (OR, 2.05; p = 0.001), and for infection (OR, 3.51; p < 0.001).[18] In conclusion, patients with DM that has caused lower leg neuropathy or internal organ damage (e.g. kidney, eye, vascular disease) are at high risk of developing complications after ankle fracture surgery, whilst patients with uncomplicated DM 'behave' in a similar fashion to non-diabetics sustaining ankle fractures.

How to fix ankle fractures in diabetics

Suboptimal stabilization of ankle fractures in patients with complicated diabetes can result in fixation failure and catastrophic complications (Fig. 3), mainly due to the onset of the Charcot neuroarthropathy process. Given that the patient's limb and probably life can be put at risk after an ankle fracture it is essential to minimize the risk of complications, if possible. The treating surgeon should also bear in mind that patients with complicated diabetes are usually of low functional demand and the goal of treatment should be limb salvage and to maintain an ambulatory status. This can be achieved by providing maximum rigidity to the fractured ankle. As mentioned earlier, cast application is not rigid enough, whilst 'standard' fixation may fail due to development of Charcot neuroarthropathy (Fig. 2, Fig. 3 and Fig. 4).

In a cohort study reviewing outcomes of failed open reduction and internal fixation (ORIF) of bimalleolar ankle fractures in 17 patients with complicated DM, revision surgeries included revision ORIF in three, external fixation in eight and ankle arthrodesis in six patients. Fourteen out of 17 limbs (82%) were salvaged. Interestingly in all those 14 patients the ankle had fused, whether this was intended (nine patients who underwent formal arthrodesis) or unintended (five patients who underwent revision ORIF or external fixation without formal fusion the ankle joint). Thus, ankle fusion resulted in limb salvage, whilst the authors also reported a reduced number of operative procedures for those patients.[19] Similar ankle fusion rates (14 out of 17) were previously reported in another study, where the author used crossed screws for fixation; however, three amputations were required.[20]

More recently, 27 patients with complicated DM and ankle fracture were treated with primary tibio-talo-calcaneal arthrodesis using retrograde hindfoot nails. Patients were followed for more than six years, and whilst the complication rate was 18.5%, there were no symptomatic nonunions or malunions, and no Charcot neuroarthropathy was reported. Eight patients had died during the follow-up period, the limb salvage rate was 96%, and 81% of patients were ambulatory.[21]

In a series of 13 patients who developed neuroarthropathy in the early period after they sustained a low-energy,

unstable ankle fracture, primary ankle arthrodesis was performed.[22] The authors chose circular external fixator or intramedullary nail to obtain arthrodesis, depending on whether patients had an open wound or not, respectively. The index surgery resulted in union in eight patients, whilst four fusions united with additional surgeries. Limb salvage was achieved in 12 out of 13 patients.

Thus, rigid fixation followed in Charcot foot reconstruction, can be adopted in ankle fracture fixation in neuropathic diabetics, using locking reconstruction plates and multiple screws, aiming at absolute stability. The type of fixation that provides maximum rigidity is primary arthrodesis of the ankle +/- subtalar joints. This can be achieved using circular external fixation, internal fixation using compression/plate fixation (Fig. 2), or retrograde tibio-talo-calcaneal (TTC) nail fixation (Fig. 4) that can actually be performed percutaneously or through small incisions without opening the fracture site (also reducing the risk of infection). The latter could be an excellent salvaging solution after failure of non-operative management, or initial 'standard' fixation, as well as for primary management of an ankle fracture in these high-risk patients with complicated DM.

Postoperative rehabilitation

Diabetes mellitus has been associated with slower bone healing, therefore prolonged immobilization and restricted weight bearing have been traditionally recommended. However, the latter has not been supported by strong scientific evidence and some publications are challenging the above 'concept', advocating early protected weight bearing in cast or boot, two weeks after surgery.[23,24]

Conclusions

An increased risk for surgical complications has been reported amongst patients with complicated diabetes. On the other hand, non-operative management is associated with higher complication rates, because inadequate stabilization can trigger the Charcot neuropathy process, and result in severe deformity and sometimes requires amputation. Arthrodesis of hindfoot joints using rigid fixation, as a primary procedure, or after failure of initial management, has been shown to be successful in salvaging the limb in approximately 80–85% of cases.

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