Classification of Diabetic Foot Disease

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Introduction

Disease classification provides a system that promotes the evidence-based treatment of complex and varied conditions through the dissemination of information, using common nomenclature. Useful classification systems have been developed to guide in the diagnosis and treatment of both Charcot arthropathy and ulcerative lesions of the foot. Classification of these two separate diabetic foot conditions is challenging as each are highly variable in location, etiology, and progression. Although there are many systems of classification for Charcot arthropathy and ulceration, only those that have contributed to the understanding of each condition are reviewed here. This chapter will discuss the classification of Charcot arthropathy and ulceration separately, as no classification system has been devised that incorporates both conditions.

Introduction to the Classification of Charcot Arthropathy

Neuropathic disintegration of the foot was first described in 1868 by the French neurologist Jean-Martin Charcot, who observed a rapidly destructive process involving the joints of patients presenting with neuropathy due to tertiary syphilis [1]. Jordan was the first to report Charcot's disease in the diabetic foot in 1936 [2]. Unlike tabes dorsalis, diabetic Charcot arthropathy almost exclusively affects the joints of the foot and ankle [3]. Today, diabetic neuropathy is recognized as the most common cause of Charcot arthropathy in the developed world.

Charcot arthropathy of the foot and ankle seemingly defies classification. It is by definition an inherently chaotic process. It may involve any joint in the foot and ankle, and it can present as multiple fractures, subluxations, and dislocations. Bizarre deformities may result, often leading to ulcerations and infections. Treatment of Charcot arthropathy is based on several factors, including the anatomic location, temporal progression, deformity, and the presence or absence of any coexisting ulceration and infection. In an attempt to facilitate our understanding of Charcot arthropathy and to standardize treatment options, numerous classification systems have been proposed.

Classification systems can be divided into two types: temporal and descriptive (anatomic). Temporal classification systems describe the stage of disease, and the only pure staging classification is the one published by Eichenholtz in 1966 [4]. Simultaneously published was an anatomic classification of Charcot arthropathy of the foot and ankle by Harris. Subsequent anatomic classification systems have been published by

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Cofield in 1983 [21]; Sammarco, and separately Schon in 1998 [29]; and Brodsky in 2006. The advantages of each will be reviewed in the subsequent sections.

Classification of the Charcot Foot and Ankle

Temporal Classification System of Eichenholtz

Perhaps the most widely referenced classification system of Charcot arthropathy was provided by Eichenholtz (Table 4.1). In 1966, he published his detailed monograph describing the clinical, radiographic, and pathologic findings in 68 consecutive patients with Charcot arthropathy of the foot and ankle [4]. Using this data, he established a classification system that described the temporal progression of the Charcot joint. Although the Eichenholtz temporal staging system is widely accepted, subsequent authors have pointed out that this system may not be inclusive of Charcot arthropathy at the earliest and latest stages of the disease. In fact, Classen et al. demonstrated that clinical symptoms, such as swelling, warmth, erythema, and even pain, frequently preceded the radiographic findings of Eichenholtz stage I by weeks or months, and that changes on bone scintigraphy could help detect early Charcot arthropathy [5]. Other authors have correctly identified that magnetic resonance imaging could detect the reactive osseous edema that precedes the changes in gross pathology [6–10]. Subsequently, in 1990 Shibata added a preceding fourth stage to Eichenholtz's classification, which was labeled as stage 0 [11]. Currently, the Eichenholtz classification is described as:

0: Foot at Risk

- Clinical—inflammation characterized by erythema, swelling, warmth, and instability
- Radiographic—absent bony changes, soft-tissue swelling may be observed
- Bone scintigraphy—increased radiotracer uptake in the involved joint
- MRI—bone and soft-tissue edema, joint effusion, noncortical stress fractures [10]

I: Stage of Development

- Known as the development-fragmentation, or acute stage, and was characterized by Eichenholtz as "debris, fragmentation, disruption, dislocation" of the joints
- Clinical—inflammation characterized by erythema, swelling, warmth, and instability
- Pathology—fragmentation of bone and cartilage. Pathognomonic of Charcot arthropathy, microscopy reveals bone debris embedded within the synovium
- Radiographic—osteopenia, fracture, subluxation and dislocation, periarticular fragmentation (Fig. 4.1a)

II: Stage of Coalescence

- This stage was initially described by Eichenholtz to demonstrate "sclerosis, absorption of fine debris, fusion of most large fragments"
- Clinical—decreased warmth, erythema, and swelling
- Radiographic—periosteal new bone formation, fracture healing, moderate joint destruction, osteopenia, and sclerosis (Fig. 4.1b)

III: Stage of Reconstruction and Reconstitution

- Eichenholtz described this stage as "lessened sclerosis, rounding of major fragment, with some attempts at reformation of joint architecture"
- Also referred to as the "chronic stage"
- Clinical—absence of inflammation, appears to be a stable deformity
- Radiographic—joint arthrosis, osteophytes, subchondral sclerosis, healing fractures, advanced deformity (Fig. 4.1c)

Although this classification system suggests that any deformity progression is minimal after stage II, more recent studies have refuted this finding. Hastings demonstrated that lateral arch collapse can progress for up to two years after the initiation of conservative treatment. This suggests that the period of instability may extend well beyond stage II, and that the stage III deformity, characterized by Eichenholtz as stable, may not be as static as once thought [12]. Additionally,

Table 4.1 Modified Eichenholtz classification of charcot arthropathy

	Clinical features	Radiographic features	MRI findings [12]	Treatment
Stage 0—Prodromal stage	• Swelling, warmth, and hyperemia	• Normal	• Bone and soft-tissue edema	• Offloading and immobilization
	• Instability	• Soft-tissue swelling may be seen	• Joint effusion	
			• Subcortical bone fractures may be seen	
Stage I—Stage of Fragmentation	• Swelling, warmth, and hyperemia	• Fractures w bone fragmentation	• Bone and soft-tissue edema	• Offloading and immobilization
	• Increased instability	• Osteopenia	• Joint effusion	
	• Deformity	• Subluxation, dislocation, and deformity	• Fractures	
			• Subluxation, dislocation, and deformity	
Stage II—Stage of Consolidation	• Decreased swelling, warmth, and hyperemia	• Reabsorption of fracture fragments	• Reduction in bone and soft-tissue edema	• Offloading and immobilization
	• Decreased instability	• Reduced osteopenia	• Reduced joint effusion	• Charcot restraint orthotic walker (CROW)
	• Deformity	• Sclerotic bone	• Callus formation	
		• Subluxation, dislocation, and deformity	• Subluxation, dislocation, and deformity	
		• New bone formation		
Stage III—Stage of Reconstruction	• Absence of swelling, warmth, and erythema	• Rounding of remaining fracture fragments	• Residual bone edema	• Custom inlay shoes with rocker-bottom sole for plantigrade foot
	• Stable deformity	• Sclerosis	• Residual joint effusion	• CROW for nonplantigrade foot versus surgical reconstruction
		• Subluxation, dislocation, and deformity with subsequent arthrosis	• Subchondral erosions	
			• Subluxation, dislocation, and deformity	

Fig. 4.1 Radiographic findings in Charcot arthropathy affecting the midfoot (**a**) stage of fragmentation—note fracture-subluxation of the talonavicular joint (*white arrow*) (**b**) stage of coalescence—note periosteal new bone formation and navicular fracture consolidation (*white arrow*). Talonavicular joint demonstrates destructive changes, osteopenia (*black arrow*), and adjacent sclerosis. (**c**) Stage of reconstruction—midfoot demonstrates advanced adduction deformity, and multiple healing fractures. Also notable is the involvement of the fifth metatarsophalangeal joint, which is in an earlier Eichenholtz stage. Multiple location involvement at varying stages is not uncommon

recurrence of Charcot at the same or adjacent joints, or regression to earlier temporal stages after the initiation of treatment is well described, with Osterhoff et al. reporting a recurrence in 23 % of the feet in his series [13–15, 16].

As imperfect as it may be, the Eichenholtz classification system is widely accepted. It has allowed for the meaningful discussion of treatment options based on the disease stage, it is used as to guide treatment, and it describes the progression of clinical and radiographic changes that occur in the Charcot foot and ankle. Arresting the Charcot process early, during stages 0 or 1, may prevent progression to instability and deformity leading to ulceration, infection, or other limb-threatening conditions as seen in later stages [16–18]. Although newer temporal classification systems based on MRI findings have been proposed, the utility of these has yet to be demonstrated [16–20].

Anatomic Classification System of Harris and Brand

Harris and Brand provided early insight into the process of neuropathic destruction of the foot. These authors may have been the first to associate elevated limb temperature with Charcot of the foot, by observing that warmth often accompanied the unstable neuropathic midfoot. Not only did Harris and Brand correctly suggest that an elevated limb temperature may indicate pending deformity and ulceration, but they also suggested that early intervention, in the form of total contact casting, may reduce the potential for fracture and deformity [20].

This classification system was devised based on the theory that a neuropathic fracture was initiated by trauma, and that collapse of the insensate foot occurred along one of several lines of weight-bearing force, or one of three “pillars.”

These three are identified as posterior (calcaneus), central (talus), and anterior (navicular). This classification system proposes that these lines of force, or pillars, are altered by an initiating fracture, resulting in deformity and ulceration. Based on this theory, five anatomic patterns of neuropathic destruction were proposed. These three pillars consist of:

Posterior Pillar

- Fracture of the calcaneus, with flattening of the heel, hindfoot recurvatum, subtalar subluxation, and proximal migration of the posterior calcaneal tuberosity
- Leads to ulceration under the plantar aspect of the heel

Central Pillar

- Talus is the primary area of disintegration
- May be caused by a previous posterior pillar pattern with subtalar subluxation

Anterior Pillar, Medial Arch

- Deformity is initiated by a fracture of the navicular, which causes proximal migration of the cuneiforms (Fig. 4.1a)
- Flattening of the navicular leads to articulation between the talar head and the cuneiforms
- This leads to reversal of medial arch, with ulceration frequently occurring plantar to the head of the talus

Anterior Pillar, Lateral Arch

- Dislocation and fracture of the calcaneocuboid joint
- Results in a reversal of the lateral arch of the foot
- The medial arch is preserved
- Often dominated by sepsis due to ulceration under the base of the fifth metatarsal

Cuneiform: Metatarsal Base

- Initiated by fracture of the cuneiforms
- Leads to fracture propagation across the midfoot resulting in a "broad flail pseudoarthrosis"

Although this classification system is seldom cited today, it was the first accepted anatomic classification of Charcot arthropathy. Like later anatomic classification systems, Harris and Brand identified that breakdown of the lateral arch was the most malignant type of neuropathic deformity, with a propensity for ulceration and sepsis. This is also the only classification system that explains the pattern of breakdown of the neuropathic foot using the biomechanical concept of pillars, or weight-bearing lines of force. Nonetheless, the usefulness of this classification method has been limited due to a lack of clinical and radiographic correlations, and is mainly of historical interest.

Anatomic Classification System of Cofield

Cofield et al. classified radiographic changes based on three anatomic locations and correlated these changes with ulcer formation [21]. After evaluating 116 feet in 96 patients with diabetic neuropathy, they noted that all patients with radiographic changes of the phalanges, and most with metarsophalangeal radiographic changes had adjacent ulceration. Conversely, few of the patients with radiographic changes of the midfoot and hindfoot had any ulceration. They also noted that radiographic changes as well as ulcer formation were more common in patients with type II diabetes, as well as those with severe metabolic complications such as retinopathy and nephropathy. The described three patterns are:

- ***Metatarsophalangeal or Phalangeal Involvement***: Observed in 78 of 116 feet, and almost always associated with ulceration (Fig. 4.2).
- ***Tarsometatarsal*** (***TMT***) ***Joint Destruction***: Observed in 18 of 116 feet with a wide spectrum of radiographic changes seen at the tarsometatarsal joint. These range from mild degenerative changes to fragmentation and collapse. Ulceration was unusual in this group.
- ***Destruction through the Head or Neck of the Talus***, ***Navicular and Cuneiforms***: Identified in 20 of 116 feet, with similarity to the anterior pillar, medial arch pattern as described by Harris and Brandt. Charcot changes occurred

Fig. 4.2 Radiographs demonstrate chronic Charcot arthropathy affecting the 2nd metatarsophalangeal joint as described by Cofield

through the head or neck of the talus, navicular, and the cuneiforms. Ulceration rarely occurred in this group as well.

Anatomic Classification System of Sammarco and Conti

Sammarco and Conti classified the pattern of bony destruction in 22 patients with Charcot arthropathy of the midfoot [22]. Using anteroposterior (AP) and lateral radiographs, they defined 5-anatomic patterns of Charcot midfoot involvement. The authors noted that lateral midfoot involvement predisposed patients to ulceration, a finding that is confirmed in subsequent classification systems. This classification system consisted of:

Pattern 1

- Seen in 11 of 22 2 feet
- Identified as diastasis occurring between the first and second TMT joints
- On AP radiographs, fragmentation and collapse can extend laterally across the TMT joints. The forefoot is displaced lateral to the hindfoot, with the first metatarsal displaced only slightly lateral to a reference line along the talar neck
- Lateral radiographs demonstrate dorsal forefoot displacement

Pattern 2

- Observed in 4 of 22 feet
- Destructive changes are identified at the medial metatarsal-cuneiform joints without diastasis of the first and second metatarsals
- There is no involvement of the metatarsal-cuboid joints, and less lateral displacement of the metatarsals compared to pattern 1

Pattern 3

- Observed in 3 of 22 feet
- Arthropathy of the medial cuneiform-navicular joint with fragmentation of the middle cuneiform bone
- Destructive changes are identified in the lateral TMT joints

Pattern 4

- Observed in 2 of 22 feet
- Identified as bony destruction of the first metatarsal-medial cuneiform joint, with diastasis occurring between the first and second metatarsals
- Proximal and lateral extension occurs across the lateral intercuneiform joints and can involve the calcaneocuboid joint

Pattern 5

- Observed in 2 of 22 feet
- Consists of perinavicular bony destruction with distal intertarsal extension

Anatomic Classification of Brodsky

The Brodsky classification of Charcot arthropathy was developed from a series of 120 patients with Charcot arthropathy, who were treated at Ranchos Los Amigos Hospital in Los Angeles, CA., in the years prior to 1985 [23]. Based on a review of records and radiographs from this series of patients, Brodsky et al. classified Charcot arthropathy

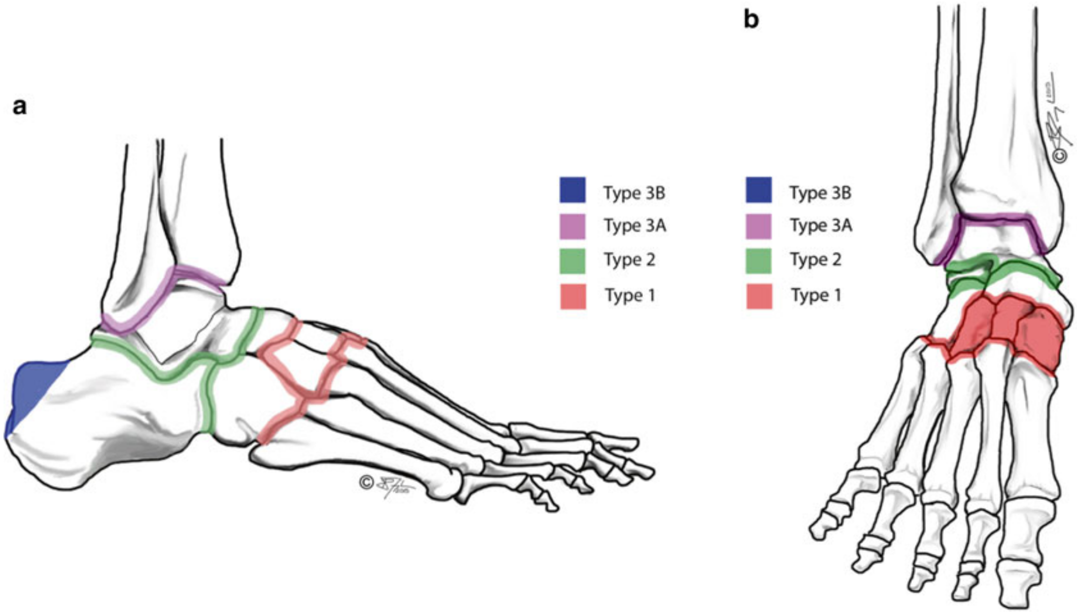

Fig. 4.3 Brodsky anatomic classification of Charcot arthropathy of the foot and ankle (**a**) lateral view (**b**) anterior view

according to the area of the foot in which maximum bony destruction occurred radiographically [24, 25] (Fig. 4.3). The utility of Brodsky's anatomic classification system lies in its simplicity. It remains the most widely quoted anatomic classification systems of Charcot arthropathy of the foot and ankle. This classification emphasizes that the more proximal the disease (the greater the Brodsky Type), the more unstable the involved joint, and the greater the potential for Charcot progression. This classification has been further modified by Trepman et al. to include types 4 and 5 [26]. The classification currently consists of:

Type I: Tarsometatarsal or Naviculocuneiform Joints

- This is identified in approximately 60 % of cases
- Typically presents later in the disease process than with Brodsky types II and III, and frequently presents during Eichenholtz stage II or III, when the foot is stable but deformed
- Frequently results in a fixed rocker-bottom foot with valgus angulation
- Often leads to the development of a plantar exostosis, which produces a risk of ulceration (Fig. 4.4)

Type II: Subtalar and or Chopart Joints (Fig. 4.5)

- Identified in 30–35 % of cases
- Typified by instability, this type is less likely to develop ulcerations than type I. Up to one-third can develop bony prominences
- Patients have persistent enlargement of the foot and often require periods of immobilization lasting up to 2-years
- The hindfoot tends to rest in a subluxed position, resulting in persistent valgus alignment

Type 3A: Ankle Joint

- Identified in 20 % of cases
- Charcot arthropathy involving the ankle is often initiated by a traumatic fracture in a neuropathic patient
- This type is characterized by a prolonged Eichenholtz stage I, and is the most unstable of all the Brodsky Types
- Produces chronic swelling and instability. May cause late varus or valgus deformities, leading to collapse and ulceration over the malleoli (Fig. 4.6)

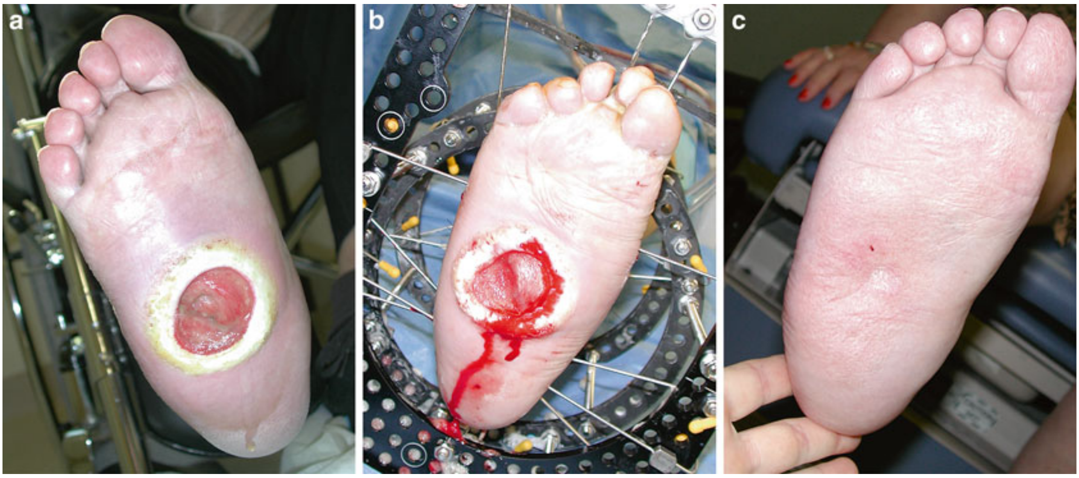

Fig. 4.4 Clinical findings of Brodsky type I Charcot arthropathy (**a**) midfoot ulceration and sepsis (**b**) surgical reconstruction with debridement of bone and soft tissues (**c**) ulcer healing after successful arthrodesis

Fig. 4.5 Radiographic findings in Brodsky type II Charcot arthropathy (**a**) neuropathic fracture of the talus with subluxation of the subtalar joint and dislocation of the talonavicular joint (**b**) this highly unstable pattern progressed to flattening of the talus, extrusion of the talar head into the medial soft tissues, and a profound adduction–supination deformity with lateral rocker-bottom

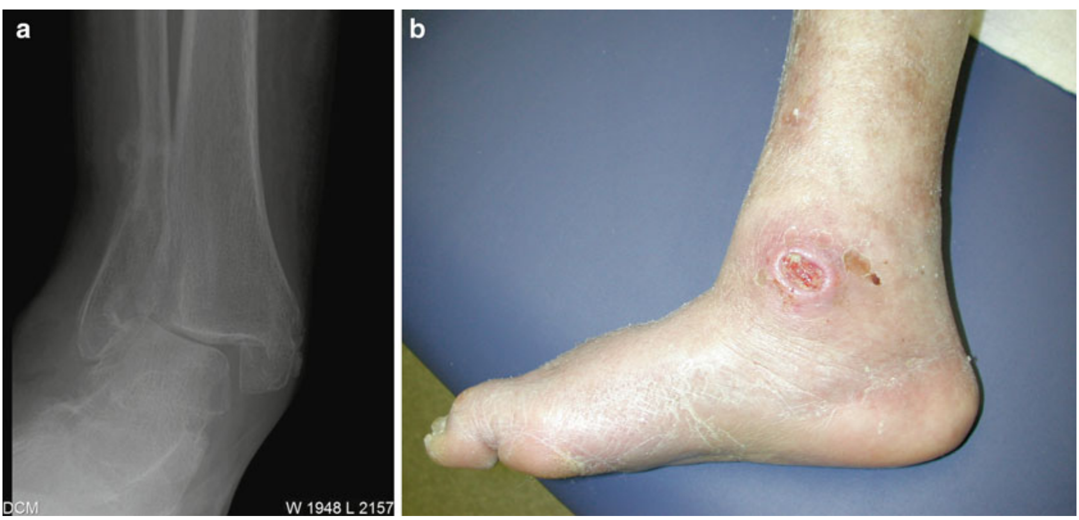

Fig. 4.6 Findings in Brodsky type 3A Charcot arthropathy (**a**) Anteroposterior (AP) radiograph obtained almost one year after presentation shows a severe valgus deformity (**b**) Associated ulceration over the medial malleolus

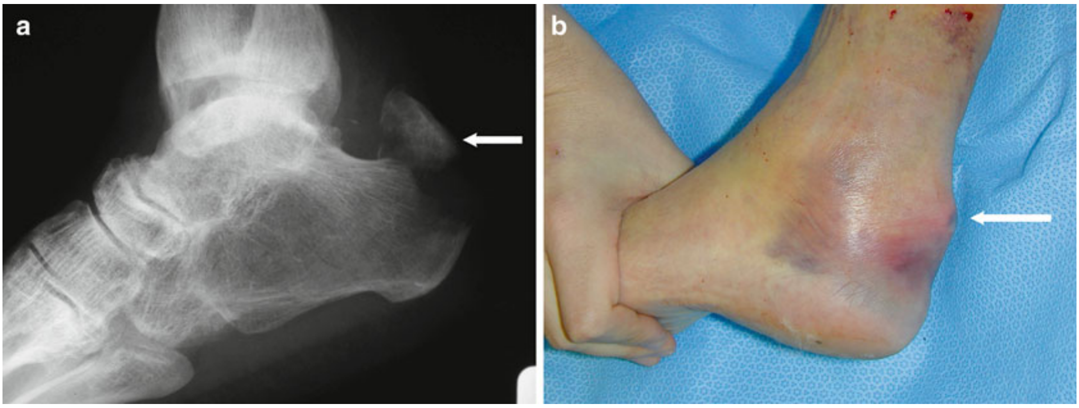

Fig. 4.7 (**a**) Lateral radiograph showing avulsion fracture of the calcaneal tuberosity (*white arrow*) as seen in Brodsky type 3B Charcot arthropathy (**b**) Clinical view showing associated soft-tissue compromise (*white arrow*)

Type 3B: Fracture of the Calcaneal Tuberosity

- Identified in fewer than 1 % of cases [23]
- This type results from bony avulsion of the Achilles tendon insertion (Fig. 4.7a)
- Causes distal foot changes and proximal migration of the tuberosity fragment
- Leads to distal collapse of the longitudinal arch of the foot
- May compromise skin in area overlying fracture, and may require immediate treatment in order to avoid skin necrosis [27, 28] (Fig. 4.7b)

Type 4: Combination of Areas

- Multiple simultaneous locations, often in different Eichenholtz stages (Fig. 4.1c)
- Concurrent involvement may be unilateral or bilateral

Type 5: Forefoot Involvement

- Only involves the forefoot
- Similar to Trepman et al. and Cofield et al., and it is often associated with ulceration and the development of osteomyelitis

Anatomic Classification System of Schon

Schon et al. established a detailed clinical and radiographic classification of acquired midtarsus deformities based on a series of 131 feet, including 86 with diabetic neuroarthropathy [29]. This system established four types of midfoot arthropathy based on the location of maximal deformity, as seen on AP and lateral weight-bearing radiographs (Table 4.2, Fig. 4.8). Concise radiographic parameters are used to define each deformity type, and the location of bony prominence for each deformity is provided. Like authors before them, Schon et al. recognized that collapse of the lateral column of the foot was associated with severe deformity and a poor outcome. Using this pretext, a novel measure of lateral arch collapse, using the lateral calcaneus-fifth metatarsal, was devised, which was shown to be decreased with lateral column involvement (Fig. 4.9a, angle C), and closely correlates with other measures of lateral column collapse including decreased calcaneal pitch (Fig. 4.9a, angle D), and reduced lateral radiographic arch height of the foot (Fig. 4.9a, measure E). From this same series of patients, Schon et al. devised a **clinical deformity severity stage** based on the degree of collapse of the longitudinal arch of the foot (Fig. 4.10).

These deformities consisted of three types:

- ***Stage A***—minimal deformity, with arch still present
- ***Stage B***—loss of medial or lateral arch with plantar or medial prominence
- ***Stage C***—collapse of arch medially and laterally, with midfoot prominence that protrudes plantar beyond a line drawn between the heel and the ball of the foot

Table 4.2 Schon radiographic and clinical classification of acquired midtarsus deformities

Type	I—Metatarsocuneiform/metatarsocuboid or Lis-Franc pattern	II—Naviculocuneiform/metatarsocuboid pattern	III—Perinavicular pattern	IV—Transverse tarsal pattern
Frequency (%)	33	46	13	8
Location of maximum deformity	• First, second, and third metatarsocuneifom joints	• Medial naviculocuneiform joint	• Navicular and surrounding bones	• Talonavicular joint
	• Progresses to the fourth and fifth metatarsocuboid joints	• Progresses to the fourth and fifth metatarsocuboid joints	• Progresses laterally through the tarsometatarsal or calcaneocuboid joints	• Progresses laterally through the calcaneocuboid joint
				• Earliest and most severe lateral column involvement
Type of deformity	• 81 % are abducted	• 62 % are abducted	• Adduction	• Abduction
	• Remainder are neutral or adducted	• Minority were adducted or neutral	• Lateral rocker-bottom deformity	
Location of prominence	• Medial, plantar-medial	• Plantar-lateral and plantar-central, less commonly medial	• Plantar-central, or plantar-lateral	• Medial, plantar-medial, or plantar-central prominence
	• Centrally with progression			
Distinctive radiographic features	• Relative preservation of lateral arch height	• Greater loss of lateral arch height compared to type I; with calcaneal pitch an average of 0°	• Largest lateral talo-first metatarsal angle of all the types	• Greatest talocalcaneal angle of all types
	• Greatest AP talo-1st metatarsal angle of all groups	• Less abduction of the midfoot is seen compared to type I deformity, as indicated by a smaller AP talar-first metatarsal angle	• Lateral column involvement resulting in a lower calcaneal pitch than in type I	• Loss of lateral arch height, as manifested by a negative calcaneal pitch, was the greatest of all four types
			• Lateral arch height significantly depressed	

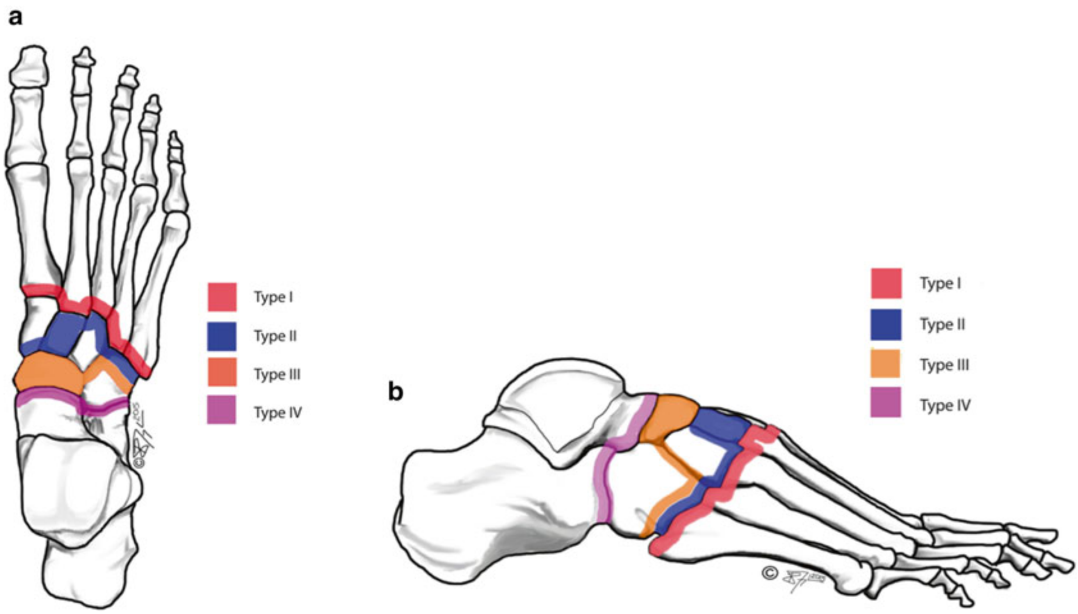

Fig. 4.8 Schon classification of acquired midtarsus deformity (**a**) dorsal view (**b**) lateral view

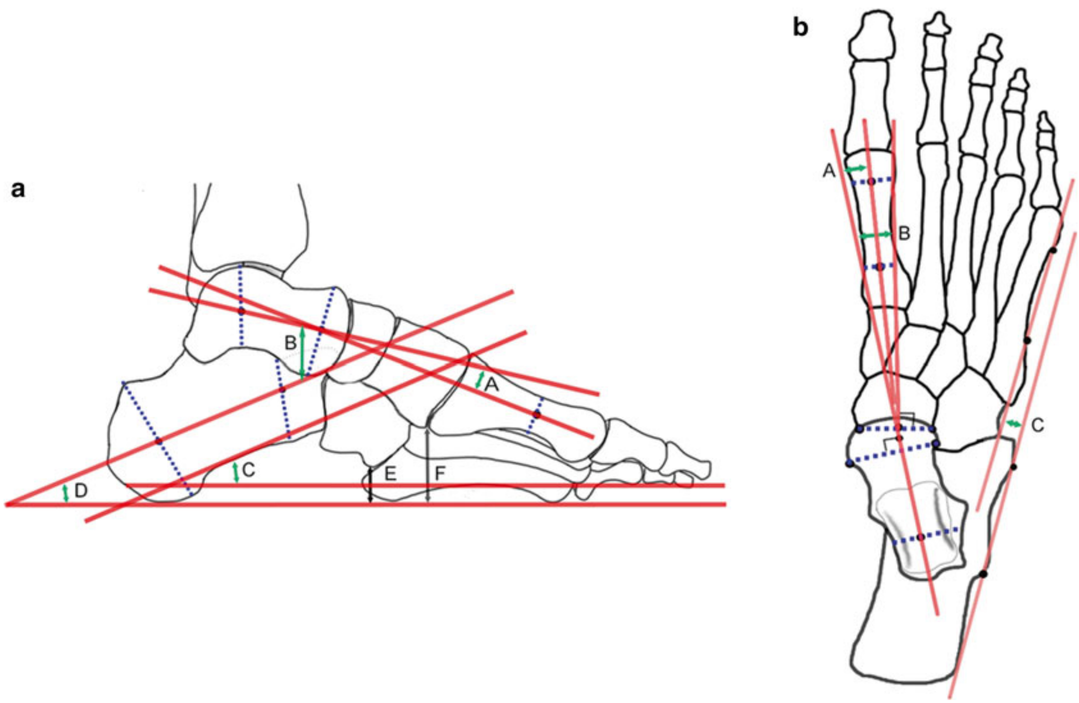

Fig. 4.9 Radiographic measurements and angles for quantifying midtarsal deformities (**a**) lateral radiographs: talar-first metatarsal angle (A); talocalcaneal angle (B); calcaneal-fifth metatarsal angle (C); calcaneal pitch (D); lateral column height (E); medial column height (F) (**b**) AP radiographs: talar-first metatarsal angle (A); talonavicular coverage angle (B); calcaneal-fifth metatarsal angle (C)

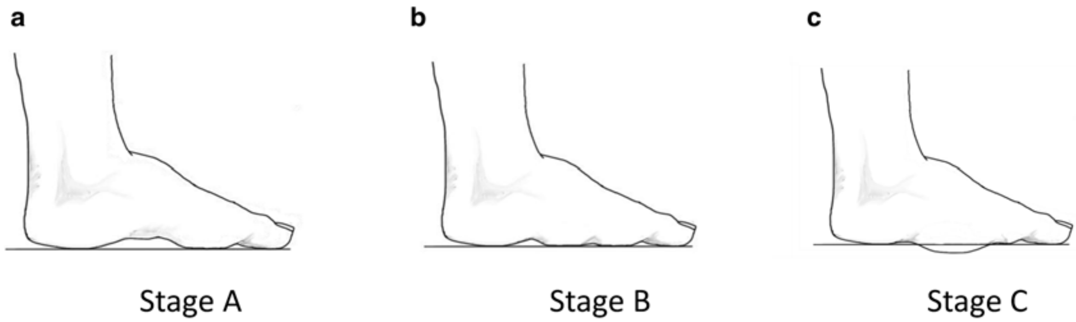

Fig. 4.10 Clinical severity deformity staging as described by Schon: Stage A—minimal deformity, with arch still present; Stage B—loss of medial or lateral arch with plantar or medial prominence; Stage C—collapse of arch medially and laterally, with midfoot prominence that protrudes plantar beyond a line drawn between the heel and the ball of the foot

A **radiographic severity scale** was later added to the original classification system of Schon et al. [30]. The authors identified three radiographic angles that were easy to measure, highly reproducible, and strongly correlated with clinical deformity:

Lateral view: talar-first metatarsal angle (Fig. 4.9a, angle A)
Lateral view: calcaneal-fifth metatarsal angle (Fig. 4.9a, angle C)
AP view: talar-first metatarsal angle (Fig. 4.9b, angle A)

Based on the measurement of these three angles, mild-to-moderate deformities are classified as an ***alpha*** stage, while the more severe ***beta stage*** of deformity is assigned if one or more of the criteria, listed below, are met:

1. Dislocation of joints identified on AP, lateral, or oblique radiographs
2. Lateral talar-first metatarsal angle ≥30°
3. Lateral calcaneal-fifth metatarsal angle ≤0°
4. AP talar-first metatarsal angle ≥35°

The addition of the radiographic severity scale was significant, because it demonstrated that a beta stage deformity correlated with prognosis and treatment. Currently the classification of Schon et al. consists of:

Type I: Metatarsocuneiform/Metatarsocuboid or Lis-Franc Pattern

- Encompasses 33 % of all deformities
- Bony destruction occurs at the first, second, and third metatarsocuneiform joints, and progresses laterally towards the fourth and fifth metatarsocuboid joints
- Clinically, these feet are widely abducted, due to medial column breakdown, and flattening of the medial arch
- Midfoot abduction, using the AP talo-1st metatarsal angle (Fig. 4.9b, angle A) is greatest among all groups, averaging 22° (Fig. 4.11)
- Lateral involvement is the least severe because the calcaneal-fifth metatarsal angle (Fig. 4.9a, angle C), and the lateral column height (Fig. 4.9a, measure E) are preserved as compared to types II–IV
- Exostosis tends to occur medial, plantar-medial, and even centrally with progression

Type II: Naviculocuneiform/Metatarsocuboid Pattern

- Is seen in 46 % of all deformities
- The major deformity occurs at the medial naviculocuneiform joint, and lateral involvement of the tarsometatarsal joints occurs during later stages
- As measured by the AP talar-first metatarsal angle, (Fig. 4.9b, angle A) the majority of feet demonstrate forefoot abduction, although to a

lesser degree than with type I deformities. A minority of feet are adducted or in a neutral position
- The lower lateral column height (Fig. 4.9a, Measure E) demonstrates that the lateral arch height is decreased and that there is also a lower calcaneal pitch (Fig. 4.9a, Measure E Fig. 4.12) relative to feet with type I deformities
- Exostosis occurs most commonly on the plantar-lateral and plantar-central areas of the foot, less commonly medially

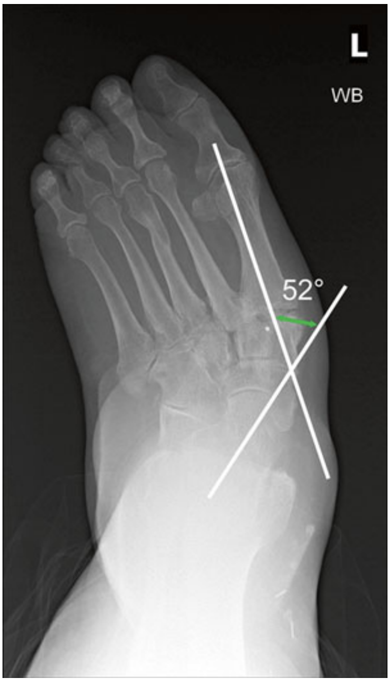

Fig. 4.11 AP radiographic findings in Schon type I midtarsus deformity. Note the severe midfoot abduction as manifested by exceptionally large AP talar-first metatarsal angle

Type III: Perinavicular Pattern
- Identified in 13 % of all deformities
- The major deformity occurs medially at the navicular and surrounding bones, and progresses laterally through the tarsometatarsal or calcaneocuboid joints
- This pattern produces the most clinically significant deformity of all four types, with pronounced adduction and rocker-bottom deformity. The lateral talar-first metatarsal angle is the greatest of all types, and lateral column height is depressed (Fig. 4.13)
- Lateral column involvement results in a lateral rocker-bottom deformity and plantar-central or plantar-lateral bony prominence

Type IV: Transverse Tarsal Pattern
- Identified in 8 % of all deformities
- Bony destruction occurs through the Chopart (talonavicular-calcaneocuboid) joint, with maximum radiographic deformity occurring through the talonavicular joint

Fig. 4.12 Lateral radiographic findings in Schon type II midtarsus deformity. Note the rocker-bottom deformity as manifested by reversal of the normally positive calcaneal pitch angle

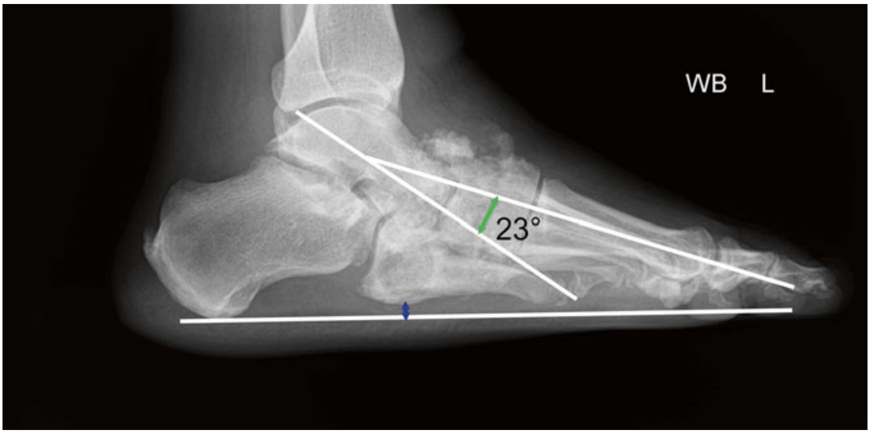

Fig. 4.13 Lateral radiographic findings in Schon type III midtarsus deformity. Increase in talar-first metatarsal angle (*green arrow*), depressed lateral column height (*blue arrow*)

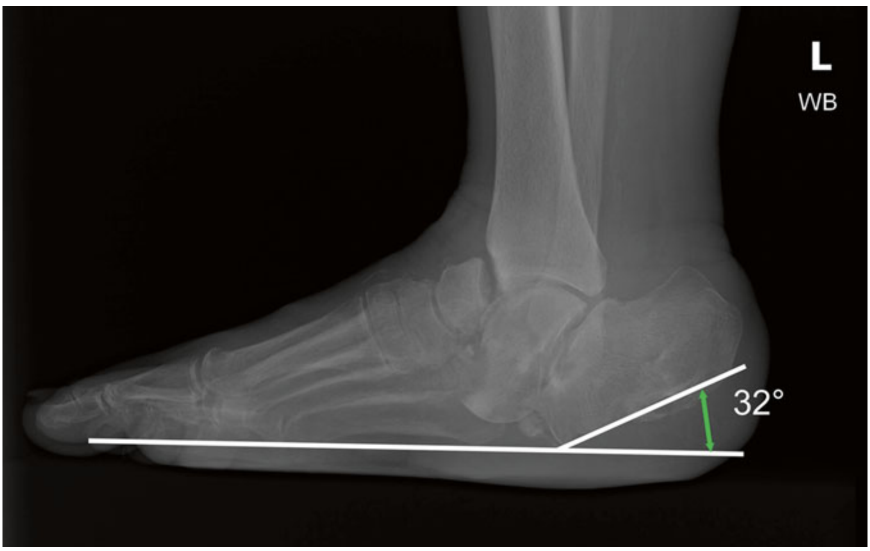

Fig. 4.14 Lateral radiographic findings in Schon type IV midtarsus deformity. Note the severe rocker-bottom deformity and extreme reversal of calcaneal pitch angle

- The deformity occurs proximally, producing an abduction deformity, with medial, plantar-medial, or plantar-central exostosis. Early lateral column involvement is common, and portends a poor prognosis due to lateral rocker-bottom deformity and ulceration
- Radiographically, talocalcaneal angle is greater than in types I–III, and loss of lateral arch height, as manifested by a negative calcaneal pitch, is the greatest of all four types (Fig. 4.14)

Summary of the Classification of the Charcot Foot and Ankle

Two types of classification systems for Charcot arthropathy have been reviewed- temporal and anatomic. Temporal classification systems provide reliable information about prognosis and expected progression of disease. The Eichenholtz system is the only temporal classification developed and describes the progression of Charcot arthropathy both clinically and radiographically. Most importantly, the Eichenholtz system provides general treatment guidelines, particularly when combined with anatomic systems of classification. Stage 0 added by Shibata, should be included when discussing the temporal classification of Charcot arthropathy, as this stage may represent an opportunity for early treatment, which may prevent progression to later stages [11].

As discussed, there are numerous anatomic classification systems. Although each system provides insights into Charcot arthropathy, the anatomic classification systems of Schon et al. and Brodsky et al. appear to be the most useful in guiding and discussing treatment. The classification by Schon et al. is important because it provides insight into specific patterns of Charcot arthropathy of the midfoot, and uses radiographic measurements to highlight the unique anatomic differences between distinct types of arthropathy. Additionally, the location of maximum bony prominence is correlated with each type of deformity, which may help guide treatment. However, the system of Schon et al. is useful only to classify disease of the midfoot.

The most comprehensive anatomic system developed however, is the one described by Brodsky et al. This system is simple to use and correlates well with the rate of progression through Eichenholtz's temporal stages. Additionally, it may help guide treatment, depending on the propensity for instability, deformity, and ulceration specific to each pattern. The weakness of this system lies in its simplicity, and unlike other anatomic classifications, Brodsky's classification does not distinguish between relatively benign forms of midfoot Charcot, such as isolated tarsometatarsal patterns, and those with a worse prognosis such as perinavicular patterns.

Classification of the Charcot foot should include both a temporal and anatomic system. The Eichenholtz temporal classification system should be used for staging, while either the Schon et al. or the Brodsky et al. anatomic classifications should be applied to describe the location of disease. Combining an anatomic and temporal classification allows the treating physician to make more accurate predictions regarding the behavior of each case of Charcot arthropathy, while using such information to guide treatment. Furthermore, combined temporal staging and anatomic classification should facilitate future discussions in the scientific literature around this complex and difficult-to-generalize condition.

Classification of Ulcerative Lesions of the Diabetic Foot

Diabetic foot lesions have many classifiable parameters. These include size, location, depth, etiology, the presence of Charcot arthropathy, deformity, and the degree of neuropathy. Furthermore, multiple host factors, including glycemic control, nutritional status, and medical comorbidities, and local factors, such as ischemia and deep infections, may ultimately impact the timing and method of treatment of an ulcer. The precise classification of diabetic foot lesions would need to account for each of these variables and would create a classification system so complex as to defy common usage. Therefore, the most widely cited and used classification systems of diabetic foot ulcers strike a balance between precision and utility, and divide this diverse cohort into groups that allow for common treatment, such as mechanical offloading, surgical debridement, or vascular intervention. The four most commonly cited classification systems of diabetic foot ulcers consist of the: Wagner-Meggitt, Depth-ischemia, University of Texas, and the International Working Group on the Diabetic Foot (IWGDF) systems.

Wagner and Meggitt Classification of Diabetic Foot Lesions

The most widely referenced classification system of diabetic foot ulcers is the Wagner-Meggitt classification. F. William Wagner, Jr. M.D., and Bernard Meggitt, F.R.C.S. developed this system in the 1970s at Ranchos Los Amigos Hospital in Los Angeles [31]. This system classifies three independent conditions along the same continuum: ulceration, infection, and ischemia and

Table 4.3 Wagner–Meggitt classification of diabetic foot lesions (Fig. 4.16)

Grade 0	• No open lesions
	• History of previous ulceration, or predisposing bony prominence or deformity
Grade 1	• Superficial ulcer without penetration to deeper layers
Grade 2	• Exposed deep structures including tendon, joint capsule, or bone
Grade 3	• Deep tissue involvement with abscess or osteomyelitis
Grade 4	• Gangrene of some portion of toe, toes, or forefoot
	• Gangrene may be wet or dry, infected or noninfected
Grade 5	• Whole-foot gangrene

established six grades of diabetic foot lesions (Table 4.3) [32] (See Appendix, Table 2). The first three of these grades (0–2) are defined according to the depth of the lesion, which is determined by the type of exposed tissue, after excision of devitalized layers. Grade 3 ulceration is characterized by the presence of exposed bone and deep infection, while the final two grades (4 and 5) are defined by the presence and extent of ischemia. The Wagner-Meggitt classification is simple, widespread in its application, and it has formed a basis for the development of subsequent systems. Based on this system, Wagner established grade-specific treatment protocols [33]. Calhoun et al. demonstrated that when grade-specific treatment protocols were followed, outcomes were markedly improved [34]. Many of the treatment principles outlined by Wagner, using this classification, are still largely applicable today.

As insightful as it is, the Wagner-Meggitt classification is based on the misconception of progression. Wagner and Meggitt believed that a grade 0 lesion (at risk for ulceration) would eventually progress in severity to stage 4 (limited ischemia) without appropriate treatment [33]. Although progression and regression of lesions along the Wagner-Meggitt grades may occur for grades 0–2, there is little evidence to support the concept of regression once a grade 3 (ulceration with exposed bone and osteomyelitis) or even limited ischemia (grade 4) has occurred. However, Wagner and Meggitt did acknowledge that stage 5 lesions (whole-foot ischemia) were unique and not reversible. In reality, it is easy to appreciate that a deep infection (grade 3) can occur in the foot with a grade one lesion, or that ischemia (grade 4 and 5) may coexist with any of the lower grade lesions (Fig. 4.15). Therefore, resolution of this classification dilemma requires grading systems that independently account for infection and ischemia.

Fig. 4.15 Ischemia occurring in the presence of ulceration. This lesion would be graded according to the depth-ischemia classification system as Grade 2B (exposed deep structures including tendon or joint capsule, and ischemia without gangrene)

Depth-Ischemia Classification of Diabetic Foot Lesions

The depth-ischemia classification (DIC), by Brodsky et al., was developed to clarify initial decision-making when treating diabetic foot

Table 4.4 Depth-ischemia classification of diabetic foot lesions

Depth Classification	
Grade 0	• No open lesions, but foot is at risk
	• Predisposed to ulceration due to a combination of peripheral neuropathy and bony prominence
Grade 1	• Superficial wound without penetration to deeper layers by sight or probing
Grade 2	• Exposed deep structures including tendon or joint capsule
Grade 3	• Exposed bone and/or deep infection
	• Abscess and/or osteomyelitis
Ischemia Classification	
Grade A	• Not ischemic
	• Foot has excellent pulses, color, capillary refill, and hair growth
Grade B	• Ischemia without gangrene
	• Absence of one or more Grade A criteria
	• Absence of gangrene
Grade C	• Partial (forefoot) gangrene
Grade D	• Complete foot gangrene

lesions [35]. In contrast to the Wagner-Meggitt system, the depth-ischemia classification adds an alphabetic designation, which describes the degree of ischemia, based on clinical parameters. It also groups deep infections into a single grade (Grade 3). Emphasis is placed on the semiautonomous nature of ulceration and ischemia, creating a more precise classification of diabetic foot lesions (Fig. 4.15).

However, this system is similar to Wagner-Meggitt in many ways. First, it doesn't really distinguish lesion depth (Table 4.4). Secondly, it does not allow for the fact that a deep infection may occur in the setting of a more superficial-depth wound, or grade. Lastly, neither system accounts for deep abscess or osteomyelitis occurring in the setting of superficial ulceration.

University of Texas Classification of Diabetic Foot Lesions

The University of Texas Classification System (UTCS) expands on the depth-ischemia, as well as the Wagner-Meggitt classification systems

Table 4.5 University of Texas classification of diabetic foot lesions

Depth Grade	
Grade 0	• Preulcerative or postulcerative lesion completely epithelialized
Grade 1	• Partial or full-thickness superficial ulceration
Grade 2	• Deep wound that involves tendon or joint capsule
Grade 3	• Wound that penetrates to bone
Infection and ischemia stage	
Stage A	• Clean wound
Stage B	• Nonischemic infected wound
Stage C	• Ischemic noninfected wound
Stage D	• Ischemic infected wound

[35, 36]. The UTCS uses numeric staging of wound depth that is similar to the DIC, but provides greater specificity than previous systems. By using an alphabetic grading system, it accounts for the presence or absence of both ischemia and infection (Table 4.5). A recent study, using both the Wagner-Meggitt and the University of Texas systems to classify diabetic foot lesions in 194 patients, found that the UTCS, by accounting for ischemia and infection, more accurately predicted outcomes [37].

International Working Group on the Diabetic Foot Classification of Diabetic Foot Lesions

The most comprehensive classification of diabetic foot lesions was developed through the combined efforts of the International Working Group of the Diabetic Foot (IWGDF) and the Infectious Disease Society of America (IDSA) [38, 39]. This system was designed to facilitate research communication, and is therefore, somewhat cumbersome for routine clinical application. The classification is based on expert consensus and categorizes diabetic foot ulcers using the following parameters: *P*erfusion, *Extent* and size of the lesion, *D*epth and tissue loss, *Infection* severity, and *S*ensation. Within each category, lesions are graded according to objective measurements and

Table 4.6 International Working Group of the Diabetic Foot classification of diabetic foot ulcers

Perfusion	
Grade 1	No signs or symptoms of peripheral arterial disease (PAD) in the affected foot, in combination with:
	• Palpable dorsal pedal and posterior tibial artery or
	• Ankle-brachial index (ABI) 0.9–1.10 or
	• Toe-brachial index (TBI) >0.6 or
	• Transcutaneous oxygen pressure (tcpO2) > 60 mmHg
Grade 2	Signs or symptoms of PAD, but not of critical limb ischemia (CLI):
	• Presence of intermittent claudication (in case of claudication, additional noninvasive assessment should be performed) or
	• ABI < 0.9, but with ankle pressure >50 mmHg or
	• TBI < 0.6, but systolic toe blood pressure >30 mmHg or
	• TcpO2 30–60 mmHg or
	• Other abnormalities on noninvasive testing, compatible with PAD (but not with CLI)
Grade 3	Critical limb ischemia, as defined by:
	• Systolic ankle blood pressure <50 mmHg or
	• Systolic toe blood pressure <30 mmHg or
	• TcpO2 < 30 mmHg
Extent/size	
• Determined after debridement	
• Measured in square centimeters by multiplying the largest diameter by the second largest diameter that is perpendicular to the first measure	
Depth/tissue loss	
• In setting where ulcer does not penetrate deep to skin, but deep infection is present by virtue of abscess or osteomyelitis, the infection is deemed to be deep, to the level of the involved structures	
Grade 1	• Superficial full-thickness ulcer, not penetrating any structure deeper than the dermis
Grade 2	• Deep ulcer, penetrating below the dermis to subcutaneous structures, involving fascia, muscle, or tendon
Grade 3	• All subsequent layers of the foot involved, including bone and/or joint (exposed bone, probing to bone)
Infection	
• Infection is a clinical diagnosis, based on the features described in this grading system, regardless of the results of wound culture	
• Three parameters are of importance when grading for infection, and directly impact treatment and outcome: involvement of skin, involvement of deeper structures, and systemic inflammatory response	
Grade 1	Absence of signs or symptoms of infection
Grade 2	Infection involving the skin and the subcutaneous tissue only (without involvement of deeper tissues and without systemic signs, as described below). At least two of the following findings are present:
	• Local swelling or induration
	• Erythema >0.5–2 cm around the ulcer
	• Local tenderness or pain
	• Local warmth
	• Purulent discharge (thick, opaque to white, or sanguineous secretion)
	Other causes of an inflammatory response of the skin should be excluded (e.g., trauma, gout, acute Charcot arthropathy, fracture, thrombosis, venous stasis)
Grade 3	Deep infection as defined by:
	• Erythema >2 cm around ulcer plus at least one of non-erythema-bulleted items described in grade 2 or
	• Infection involving structures deeper than skin and subcutaneous tissues such as abscess, osteomyelitis, septic arthritis, fasciitis
	• Absence of systemic inflammatory response signs, as described in grade 4

(continued)

Table 4.6 (continued)

Perfusion	
Grade 4	Infection characterized by a systemic inflammatory response as defined by two or more of the following conditions:
	• Temperature >38° or <36 °C
	• Heart rate >90 beats/min
	• Respiratory rate >20 breaths/min
	• $PaCO_2$ < 32-mmHg
	• White blood cell count >12,000 or <4000/cu mm
	• 10 % immature (band) forms
Sensation	
• The distinction between grades is the presence or absence of protective sensation, as determined by sensation to pressure and vibration	
Grade 1	No detectable loss of protective sensation on the affected foot, as defined by the presence of sensory modalities described in grade 2
Grade 2	Loss of protective sensation on the affected foot is defined as the absence of perception of the one of the following tests in the affected foot:
	• Absent pressure sensation, determined with a 10-g monofilament, on two out of three sites on the plantar side of the foot
	• Absent vibration sensation, (determined with a 128-Hz tuning fork) or vibration threshold >25 V (using semiquantitative techniques), both tested on the hallux

criteria and is summarized by the acronym PEDIS (Table 4.6). Unlike previously discussed classifications, the infection category for this system accounts for systemic manifestations of diabetic foot infection, such as leukocytosis and acidosis, which are the end-result of untreated diabetic foot lesions and often portend a poor prognosis for limb salvage [39]. Although no study to date has verified the predictive power of this system, several studies have found that in the presence of ulceration, the IWGDF infection grade is predictive of amputation [40].

Summary of Ulcer Classifications

Numerous classification systems for diabetic foot lesions have been devised. The Wagner-Meggitt system is simple, easy to apply, and is the most commonly clinically referenced system for the classification of diabetic foot ulcers. The problems, however, are that this system assumes a progression of the ulcer, a reversal that may or may not occur, and also does not account for ischemia and infection occurring independent of wound depth. The depth-ischemia classification system accounts separately for ischemia, while the UTCS accounts separately for both ischemia and infection. Because each of these systems does address ischemia and infection, through alphabetic designations, these both may provide greater treatment-relevance and predictive power. Finally, the IWGDF classification system does focus on variables that are not addressed by other classifications, but its use as a research tool may make it too cumbersome for routine clinical use. From the author's perspective, each system has merit and additional research is needed in order to validate each of these systems. Therefore, when deciding on a system, pick one that is easy to use and remember and then use it consistently.

Fig. 4.16 Wagner-Meggitt classification of diabetic foot lesions (**a**) Grade 0: deformity created by an underlying Charcot arthropathy has created a preulcerative bony prominence beneath the subluxed talar head. (**b**) Grade 1: superficial ulceration (**c**) Grade 2: ulceration which probed to the MTP joint capsule, but absent signs of infection. (**d**) Grade 3: ulceration with exposed bone and deep infection. (**e**) Grade 4: gangrene limited to forefoot. (**f**) Grade 5: early whole-foot gangrene

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