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Relationship of Cuboid Height to Plantar Ulceration and Other Radiographic Parameters in Midfoot Charcot Neuroarthropathy

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ABSTRACT

The objective of the present investigation was to examine the effect of cuboid height on the presence of plantar midfoot ulceration and the relationship of cuboid height to other commonly performed radiographic parameters during evaluation of midfoot Charcot neuroarthropathy. A retrospective analysis was performed of 68 feet in 60 subjects who met the inclusion criteria. We did not observe statistically significant differences in the presence of a plantar midfoot ulceration when considering a cuboid height threshold of 0.0 mm, 2.0 mm, −2.0 mm, or −5.0 mm nor was the cuboid height a robust predictor for the presence of plantar midfoot ulceration when considering the positive predictive value, negative predictive value, sensitivity, or specificity. We observed a significant negative association between a negative cuboid height and the presence of Sanders Type 2 deformities (76.2% of those with negative height versus 50.0% of those with positive height had type 2 deformities; $p = .0036$), the absence of radiographic visualization of the lateral tarsometatarsal joint (71.4% of those with negative height versus 26.9% of those with positive height had an absence of radiographic visualization; $p = .005$), and lower calcaneal inclination angles (6.06° versus 15.08°; $p < .001$). We further observed significant positive correlations between the cuboid height and the calcaneal–fifth metatarsal angle (0.655; $p < .000$), calcaneal inclination angle (0.591; $p < .001$), calcaneal–cuboid angle (0.254; $p = .038$), medial column height (0.264; $p = .029$), and first metatarsal inclination angle (0.245; $p = .047$). We also observed negative correlations with Meary's angle (−0.475; $p < .001$) and the talar declination angle (−0.387; $p < .001$). These findings showed a general trend toward a decreasing cuboid height and increasing sagittal plane deformity involving both the medial and the lateral columns. The results of the present investigation provide evidence against a single radiographic parameter being associated with the presence of plantar midfoot ulceration.

Wukich et al (1) recently reported a strong association between the objective parameter of cuboid height (or lateral column height) on the lateral radiographic projection and plantar foot ulceration in patients with midfoot Charcot neuroarthropathy (CN). They observed a statistically significant difference in cuboid height between a retrospective series of midfoot CN patients with and without foot ulceration and reported that 40 of 50 patients (80%) with midfoot CN and a foot ulceration had a negative cuboid height (1). They described a negative cuboid height as one in which a structurally plantarflexed cuboid extends inferiorly beyond the plantar osseous plane of the lateral column of the foot.

Bevan and Tomlinson (2) had also previously sought to associate the radiographic angular measurements with plantar ulceration in midfoot CN. Although they did not specifically measure the cuboid height, they did find that the lateral talo–first metatarsal angle (or Meary's angle) and calcaneal–fifth metatarsal angles were sensitive parameters associated with ulceration (2). All patients with a plantar midfoot ulceration in their cohort had a Meary's angle more negative than −27°. We identified 2 other studies that described the cuboid height in association with CN deformity. Hastings et al (3) demonstrated that the cuboid height became progressively more negative in a group of diabetic patients with CN during a 2-year period, and Schon et al (4) quantified the lateral column height in groups of CN patients with differing mid-tarsus deformities.

Furthermore, Steel et al (5) provided descriptive data of the lateral column height in a group of "normal" adult feet in 1980, and Younger et al (6) also examined a group of 21 feet with adult flatfoot deformity in 2005. The latter study of flatfeet further described an intraobserver measurement (r^2 values) of 0.4 and an interobserver measurement of

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0.96 for the lateral column height and an intraobserver measurement of 0.92 and interobserver measurement of 0.95 for the calcaneus–fifth metatarsal angle. In an earlier investigation, Hastings et al (7) also described a relatively "precise" measurement of the cuboid height between 2 orthopedic surgeons and a radiology resident (a combined rater's least significant change of ≤4.7 mm).

Somewhat in line with these investigations (1–7), we have also observed in our clinical practice a trend for some patients with midfoot CN to develop a cuboid that displaces plantarly (creating a more negative cuboid height) with seemingly poor clinical outcomes. In contrast, others have developed a cuboid that displaces dorsally (creating a more positive cuboid height), with seemingly better clinical outcomes. The objective of the present retrospective, observational comparative investigation was to further examine the association of cuboid height with plantar ulceration in midfoot CN. We specifically aimed to (1) describe the association of cuboid height with the presence of plantar midfoot ulceration in a retrospective cohort of patients with midfoot CN, and (2) describe the relationship of other radiographic parameters with a cuboid height in a retrospective cohort of patients with midfoot CN.

Patients and Methods

After approval from our institutional review board, an "International Classification of Diseases" diagnostic code search was performed for all patients seen at the Temple University Foot and Ankle Institute during a 1-year data collection period (January 2015 to December 2015). The specific codes used in this search were 713.5 (Charcot's arthropathy associated with diabetes mellitus), M14.671 (Charcot's joint, right ankle and foot), M14.672 (Charcot's joint, left ankle and foot), and M14.60 (Charcot's joint, unspecified site). The electronic medical records found were then interrogated for the study inclusion and exclusion criteria. The inclusion criteria were the availability of at least anteroposterior (AP) and lateral weightbearing radiographic foot projections, evidence of midfoot CN (defined as the tarsometatarsal, midfoot, and/or transverse tarsal joints; Sanders/Frykberg classification types 2 and 3 [8]), no evidence of previous surgical reconstruction (defined as internal or external fixation of the midfoot, rearfoot and/or ankle), and no partial foot amputation or osseous resection involving the rearfoot, midfoot, any complete metatarsal, or >1 metatarsal head. The exclusion criteria were the lack of appropriate weightbearing or preoperative intervention radiographs, no radiographic evidence of CN, the presence of CN of the forefoot, subtalar joint, calcaneus and/or ankle, and any evidence of surgical reconstruction, partial foot amputation, or osseous resection involving the rearfoot, midfoot, complete metatarsal, or >1 metatarsal head. Thus, we included subjects with a history of digital amputations and/or single metatarsal head amputations but excluded those with multiple partial or complete ray amputations, including transmetatarsal amputations.

The electronic medical record was reviewed for participant age, gender, laterality of pathology, a history of lower extremity ulceration and/or amputation, and a history of eventual CN reconstruction. The radiographs were reviewed for CN classification as defined by the Sanders/Frykberg classification (8). Type 2 deformities were defined as involvement of the Lisfranc tarsometatarsal joint. Type 3 deformities were defined as involvement of the intercuneiform, cuneocuboid, naviculocuneiform, talonavicular, and calcaneocuboid joints. We also subjectively and categorically reviewed the AP radiographs to determine whether the lateral tarsometatarsal joint was visualized (Fig. 1). The lack of visualization of this joint space could have resulted from a variety of factors, including consolidation as a part of the CN process, overlapping or underlapping of the metatarsal bases on the cuboid as a part of the CN process, or severe arthritic changes. AP radiographs were further reviewed for the following radiographic parameters: AP talocalcaneal angle (Kite's angle), calcaneal–cuboid angle, and AP talo–first metatarsal angle (1,9). The lateral radiographs were reviewed for the cuboid height, calcaneal inclination angle, talar declination angle, tibial–talar angle, first metatarsal inclination angle, fifth metatarsal inclination angle, lateral talo-first metatarsal angle (Meary's angle), calcaneal–fifth metatarsal angle, and medial column height (1,9). The radiographic measurements were taken using computerized digital software (Opal-RAD PACS; Viztek, Garner, NC), which measured to a precision of 0.1° and 0.1 mm.

The cuboid height and medial column height were measured relative to a line drawn from the plantar aspect of calcaneal tuberosity to the plantar aspect of the fifth metatarsal head (Fig. 2). The cuboid height was measured as the perpendicular distance from the most inferior aspect of cuboid to this line, and the medial column height was defined as the perpendicular distance from the most inferior aspect of the first metatarsal–cuneiform articulation to this line (1,3–7,9).

The radiographic measurements were performed by 1 of us (J.S.) and confirmed by the corresponding author (A.J.M.). We attempted to be as conservative as possible regarding the radiographic measurements, given the osseous destruction that often accompanies CN. For example, we had initially planned on measuring the talonavicular coverage on the AP radiographic projections but found early in the data collection that destruction of the navicular structural integrity during the CN disease process made this measurement both difficult and unreliable; hence, we did not include it. If a given osseous landmark lacked structural integrity and made measurement of a specific angle questionable, we omitted this measurement. Furthermore, in patients with first metatarsal head resection, we did not perform measurement of the AP Meary angle, Meary's angle, or the first metatarsal inclination angle. In patients with fifth metatarsal head resection, we did not perform measurement of the fifth metatarsal inclination angle and measured the calcaneal–fifth metatarsal angle using the plantar aspect of the fourth metatarsal head.

Categorical outcomes were described in terms of frequency and were compared between groups using Fisher's exact test. Continuous outcomes were described in terms of the mean, standard deviation, and range and compared between groups using the nonpaired Student *t* test. Our primary comparisons concerned the cuboid height. We first described our findings of cuboid height in terms of the mean, standard deviation, and range and graphically depicted the results on a histogram. We then divided the cohort into those with positive (≥0.0 mm) and negative (<0.0 mm) cuboid heights

Fig. 1. Assessment of radiographic visualization of the lateral tarsometatarsal joint. *(Left)* An example of what we defined as a relatively normal lateral tarsometatarsal joint with radiographically visible joint space. *(Right)* An example of what we defined as the lack of visualization of the lateral tarsometatarsal joint space.