

Clinical Research

What Is the Interrater and Intrarater Reliability of the Lawrence and Botte Classification System of Fifth Metatarsal Base Fractures?

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Abstract

Background Fractures of the proximal fifth metatarsal are common, and often they are classified using a three-part scale first proposed by Lawrence and Botte. A clear consensus on prognosis and treatment for these fractures is lacking, particularly for fractures in the middle classification, Zone 2; the reliability of the classification scheme itself may be partly at fault for this. The intra- and interrater reliability of the classification itself has never been established, and it remains unclear whether the three-part

classification of fifth metatarsal fractures can be applied consistently enough to guide treatment.

Questions/purposes When used by experienced orthopaedic surgeons, (1) What is the overall interrater reliability of the three-part Lawrence and Botte classification of fifth metatarsal base fractures? (2) What is the overall intrarater reliability of the three-part Lawrence and Botte classification of fifth metatarsal base fractures? (3) What are these same metrics for the individual transitions within the classification (Zone 1-2 and Zone 2-3)?

Methods Thirty sets of initial presentation radiographs representing an equal number of fractures originally diagnosed by treating clinicians as Zone 1, Zone 2, and Zone 3 were evaluated and classified by three orthopaedic surgeons specializing in foot and ankle surgery and eight foot and ankle fellows to determine interrater reliability. Two weeks later, the same set of radiographs were reevaluated in random order to determine intrarater reliability. Kappa values for interrater and intrarater reliability were calculated. Additionally, the individual transitions between zones were separately analyzed by calculating kappa values for a hypothetical two-part classification based on each transition.

Results The three-part Lawrence and Botte classification of fifth metatarsal fractures demonstrated an overall interrater agreement of $\kappa = 0.66$ (observed agreement 77% versus chance agreement 33%). Intrarater reliability for the 11 surgeons ranged from $\kappa = 0.60$ to $\kappa = 0.90$. A two-part scheme divided by the transition between Zone 1 and Zone 2 demonstrated an interrater agreement of $\kappa = 0.83$, and a two-part scheme divided by the transition between Zone 2 and Zone 3 demonstrated a much lower interrater reliability of $\kappa = 0.66$.

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Conclusion The three-part Lawrence and Botte classification system demonstrated a concerning low level of interrater reliability with an observed agreement of 77% compared with a chance agreement of 33%. The primary source of concern is the assessment of the interface between Zone 2 and Zone 3, which proved much less reliable than that between Zone 1 and Zone 2. This suggests that previous studies of isolated Zone 1 fractures likely contain a homogeneous fracture cohort, whereas studies of Zone 2 or Zone 3 fractures are likely to include a mixture of fracture types. In practice, the consensus treatment of fifth metatarsal fractures differs based on whether they represent a more proximal, avulsive injury or a more distal injury from indirect trauma. Our data suggest that the Lawrence and Botte classification should be abandoned. Further work should focus on developing a new classification scheme that demonstrates improved interobserver reliability and more directly corresponds to this treatment paradigm.

Level of Evidence Level III, diagnostic study.

Introduction

Fractures of the proximal fifth metatarsal are common, with a reported annual incidence of approximately 1 per 2500 persons [18]. Confusion over classification of these fractures has existed since their original description by Robert Jones [10]. Jones himself experienced a fracture that, based on the published radiographs, appeared to enter the intermetatarsal of the fourth and fifth rays. His publication also included radiographs of his patients with fractures more distal to this location. Torg et al. [24] published a classification for a subset of these injuries that focused on only those fractures distal to the tuberosity and rated their presumed chronicity. Multiple authors subsequently described three-part anatomic divisions of fifth metatarsal fractures based on the tuberosity, the fourth to fifth intermetatarsal articulation, and the proximal metatarsal distal to this joint, beginning with Lawrence and Botte in 1993 [13]. Nearly contemporaneous identical schemes were presented by Clapper et al. [5], who described variable outcomes and treatment plans for fractures in these three locations based on a retrospective review of a fracture registry, and by Dameron [7], who described a similar system. Dameron [7] referred to fractures entering the fourth to fifth intermetatarsal articulation as “Jones” fractures, a specification that does not precisely match Jones’ original publication. Morris et al. [16] reported biomechanical data indicating that significantly greater instability is present distal to the peroneus brevis insertion, but to justify their model, they in turn cited previous work by Kavanaugh et al. [11], who noted that problematic fractures of the fifth metatarsal occurred at a location at or

just distal to the distal aspect of the fourth to fifth intermetatarsal, a key radiographically identifiable transition point used in all three-part classification schemes.

Almost 30 years after its initial presentation, the three-part classification remains the common standard for evaluating these fractures [3]. The nearly identical schemes of Lawrence and Botte [13], Clapper et al. [5], and Dameron [7] divide proximal fifth metatarsal fractures into three anatomic zones. Zone 1 tuberosity avulsion fractures are defined as a fracture of the styloid process sustained by an acute hindfoot inversion force because of the firm attachment of the lateral band of the plantar aponeurosis. Zone 2, or “Jones” fractures, using Dameron’s [7] definition, are defined as fractures extending into the fourth to fifth intermetatarsal articulation along the metaphyseal-diaphyseal junction purported to occur because of forceful adduction of the foot with a plantarflexed ankle. Zone 3 diaphyseal stress fractures are classified as pathologic fractures of the proximal shaft resulting from fatigue of the bone microarchitecture caused by repetitive forces. Controversies in treatment continue to exist, in part because of the inconsistent nomenclature surrounding the fractures and the possibility that heterogeneous patient populations may be included in clinical studies of the topic. Although some retrospective studies suggest a correlation between treatment and prognosis based on proximal fifth metatarsal fracture classification [6, 13, 17, 19, 22, 23], the commonly used three-part classification system has not been evaluated for interrater and intrarater reliability.

We therefore evaluated the Lawrence and Botte classification when used by orthopaedic foot and ankle surgeons. Specifically, we asked (1) What is the overall interrater reliability of the three-part Lawrence and Botte classification of fifth metatarsal base fractures? (2) What is the overall intrarater reliability of the three-part Lawrence and Botte classification of fifth metatarsal base fractures? (3) What are these same metrics for the individual transitions within the classification (Zone 1-2 and Zone 2-3)?

Patients and Methods

Study Design and Setting

We performed a chart review to identify patients with a diagnosis of fifth metatarsal base fractures in the electronic medical records of MedStar Union Memorial Hospital. This was done by the department of biomedical informatics at that institution using the ICD-10 codes S92.309 (metatarsal fracture) and M84.376 (metatarsal stress fracture) and the CPT codes 28470 (closed treatment of metatarsal fracture), 28476 (percutaneous treatment of metatarsal fracture), and 28485 (open treatment of metatarsal fracture) between January 1, 2016, and May 1, 2020.

Patients

Included patients were 18 to 90 years of age, of either sex, and had AP, oblique, and lateral radiographs available in the electronic medical record. The radiographs were de-identified to minimize the risk of breaching patient confidentiality.

Participating Surgeons and Evaluations

The Lawrence and Botte classification is routinely used at our institution. To assure an appropriate distribution of patients to adequately evaluate reliability, the medical record was used to identify 10 patients corresponding to each classification, as originally diagnosed and documented by the treating physician. Nonweightbearing AP, lateral, and oblique radiographs of the foot were used without any supplemental CT or MRI imaging. No pretraining of the included surgeons was completed, no consensus meeting was performed, and no visual or written summary of the system was provided. Radiographs taken at the time of initial presentation to the treating surgeon were used.

The de-identified radiographs were blinded, randomly ordered based on a random number table, and emailed to three attending orthopaedic foot and ankle surgeons and eight foot and ankle fellows. Each surgeon was asked to independently classify the fractures using the Lawrence and Botte system. No summary of the classification system or visual aids were provided. Two weeks later, the same set of radiographs were reordered in a random fashion and emailed to readers to be re-read under the same conditions. The second round of readings was utilized solely to calculate intrarater reliability.

Ethical Approval

This study was reviewed and approved by our institutional review board.

Statistical Analysis

Interrater and intrarater reliability is summarized using the κ statistic, which was developed for use by multiple readers [9]. The κ statistic is a chance-corrected measure of agreement that equals 0 if agreement is equal to what would be expected based on chance alone and 1 if there is perfect agreement among raters. [12]. Two dichotomous comparisons were performed to assess interrater reliability for the individual transitions between classification zones. The Zone 1 to 2 transition was evaluated by calculating the κ statistic for the classification of Zone 1 versus that of

combined Zones 2 and 3. The Zone 2 to 3 transition was evaluated by calculating the κ statistic for the classification of Zone 3 versus that of combined Zones 1 and 2. SAS software was used for all calculations (version 9.4, SAS Institute Inc.).

Results

Interrater Reliability

The original three-part Lawrence and Botte classification of fifth metatarsal fractures demonstrated interrater agreement of $\kappa = 0.66$ (95% CI 0.63 to 0.69). The observed agreement was 77%, compared with a chance agreement for a three-part classification of 33%.

Intrarater Reliability

Intrarater reliability for the individual raters between rounds demonstrated κ values ranging from 0.60 to 0.90,

Agreement on Transitions Within the Classification

The dichotomous comparison of classification of Zone 1 versus that of all other possibilities (Zones 2 and 3 combined) yielded much stronger agreement than that of the original three-part classification, with a kappa of 0.83 (95% CI 0.79 to 0.88). By contrast, the dichotomous comparison of classification of Zone 3 versus Zones 1 and 2 combined yielded a lower κ of 0.66 (95% CI 0.61 to 0.71).

Discussion

The three-part classification of proximal fifth metatarsal fractures first described by Lawrence and Botte [13] remains the common standard for evaluating proximal fractures of the fifth metatarsal. Determining prognosis reliably and selecting the appropriate treatment for these fractures remain challenging, particularly for fractures in Zone 2. Our findings suggest this lack of consensus may result from the inability of even experienced foot and ankle orthopaedic surgeons to agree consistently about how to apply the classification itself. The Lawrence and Botte classification system demonstrated concerning low levels of disagreement among surgeons when evaluated as a whole, with most of the discrepancies driven by a specific weakness in distinguishing Zone 2 versus Zone 3 fractures. These findings suggest that clinical conclusions regarding the differential treatment and outcomes of Zone 2 versus Zone 3 fractures may be suspect and that a new



Fig. 1 A-C (A) AP, (B) oblique, and (C) lateral radiographs show one fracture from our data with low interrater reliability distinguishing between Zone 2 and Zone 3.

classification scheme with greater reliability and utility should be developed.

Limitations

One limitation of this study is that all raters were foot and ankle orthopaedic surgeons, which may make our results less generalizable. We believe, though, that including only subspecialists may represent a best-case scenario, and the lack of agreement we identified despite the level of expertise of these raters would likely be even worse with less-experienced evaluators.

In addition, the study was designed to focus on areas of clinical controversy, and we made a conscious decision to include equal numbers of injuries originally diagnosed to be in Zones 1, 2, and 3. In clinical practice, small avulsive fractures are far more common than other types and, as our data show, these are easily distinguished. Our results are most appropriately viewed as an evaluation of the ability of raters to use a three-part classification scheme to distinguish those radiographic landmarks that have been

purported to have clinical importance rather than a definitive statement of the performance of the scheme if applied to a naturally skewed distribution of sequential cases.

Reliability of the Lawrence and Botte Classification System

Our evaluation of the component transitions in the classification scheme revealed much lower reliability for the distinction between Zone 2 and Zone 3 than for the distinction between Zone 1 and Zone 2. These transitions rely on different radiographic landmarks. The distal boundary of Zone 1 is the medial corner of the fifth metatarsal, a sharp and well-defined angular transition. The distal boundary of Zone 2 is the distal margin of the intermetatarsal facet, a less well-defined landmark. The less obvious transition between Zones 2 and 3 led to variability among raters in identifying the fracture zone (Fig. 1). The clinical importance of distinguishing between Zone 2 and Zone 3 fractures remains somewhat unclear. There are numerous studies supporting the operative treatment of Zone 3 stress fractures [4, 14, 20, 21]. Zone 2 fractures have been less thoroughly described and evaluated; several studies have demonstrated a high likelihood of union with nonoperative treatment [1, 2, 4, 15], whereas others advocate operative treatment because of faster healing [4], a higher likelihood of union [8, 11], and lower risk of refracture [22].

Only one study of which we are aware has approached the question of differential treatment of Zone 2 and Zone 3 fractures from a clinical perspective. Chuckpaiwong et al. [4] retrospectively studied 61 proximal fifth metatarsal fractures that were classified as Zone 2 or Zone 3 at the attending surgeon's discretion. No difference in treatment outcome or algorithm was noted, and the authors determined that there was no reason to continue to use this clinical distinction.

It is appropriate to question whether a three-part classification of fifth metatarsal base fractures adds any utility to guiding treatment, prognosis, or rehabilitation. We know of no clinical studies that tie the distinction between Zones 2 and 3 in this fracture classification to patient-reported outcomes after injury or treatment, and our data suggest that the interrater reliability between Zones 2 and 3 is suspect. Additionally, there is no particular reason to suspect that the distal extent of the fourth and fifth intermetatarsal facet represents an important biologic or mechanical boundary. A fracture that exits 1 mm proximal to the site is not likely to have a substantially different degree of stability or healing potential than does a fracture 1 mm distal to it.

As a practical matter, proximal fifth metatarsal fractures are broadly thought to arise as avulsions from acute inversion forces or as stress injuries from chronic indirect trauma. Within those broad categories, Morris et al. [16]

have presented biomechanical data suggesting that the peroneus brevis footprint may be an important determinant of stability in a model of avulsive injury, whereas Torg et al. [24] have demonstrated radiographic features associated with prognosis in metaphyseal-diaphyseal stress fractures. A more comprehensive and effective classification scheme would incorporate these contributions, likely by using a two-part scheme of avulsive versus stress injuries and then dividing each into appropriate subcategories to determine prognosis and guide treatment. Although our dataset is not comprehensive enough to provide robust evidence of reliability and relevance of such a scheme, we believe our findings suggest that this path for future work may be fruitful.

Conclusion

We found concerning low levels of interrater variability in the three-part Lawrence and Botte classification arising primarily from difficulty in evaluating the distinction between Zones 2 and Zones 3. Anatomically, this distinction corresponds to the distal margin of the intermetatarsal fourth to fifth facet. In conjunction with the lack of clinical data to support this boundary as an important determinant of prognosis or treatment, our data suggest the Lawrence and Botte classification should be abandoned. Future work should concentrate on development of a scheme focused on avulsive injuries versus stress fractures, with appropriate subcategories to guide treatment based on clinical data.

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