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Predictive Radiographic Markers For Concomitant Ipsilateral Ankle Injuries In Tibial Shaft Fractures

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STRUCTURED ABSTRACT

Objectives—To quantify the radiographic tibia and fibula shaft fracture characteristics that are associated with a concomitant ipsilateral ankle injury.

Design—Retrospective case-control study.

Setting—Academic level I trauma center.

Patients—Seventy-one adult patients with an operatively treated tibial shaft fracture met the inclusion/exclusion criteria.

Intervention—Preoperative radiographs were categorized according to tibia and fibula fracture pattern, location and spatial relationship to each other. Preoperative CT scans were then evaluated to assess for the presence of an articular ankle injury.

Main Outcome Measurements—1) incidence of concomitant tibial shaft fracture and ipsilateral ankle injury; and 2) statistical association between tibia and fibula fracture characteristics in patients with and without an ipsilateral ankle fracture.

Results—Thirty-five of 71 (49.3%) tibial shaft fracture patients had a concomitant ipsilateral ankle injury. Of these, 31 (88.6%) ankle injuries occurred in patients with a spiral pattern tibia fracture of the distal third diaphysis ($p < 0.001$). A spiral pattern tibia fracture, a distal one-third tibial shaft fracture location or a spiral pattern fibula fracture all were significantly associated with the presence of an ipsilateral ankle injury ($p = < 0.001$; $p = 0.001$; and $p = 0.002$). Patients with either a transverse pattern or absent fibula fracture, a non-spiral pattern tibia fracture or a midshaft diaphyseal tibia fracture location were significantly less likely to have an associated ankle injury ($p = < 0.001$; $p = < 0.001$; and $p = 0.012$).

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Conclusions—Ipsilateral ankle fractures are commonly associated with tibial shaft fractures, specifically distal one-third spiral type injuries. Recognition of an associated ankle injury is important as it can alter operative and postoperative management. Clinical studies are needed to examine patient outcomes with or without ipsilateral ankle injury to determine the clinical significance of this entity.

Keywords

Tibial shaft fracture; concomitant ankle injury; predictive radiographic patterns; spiral

INTRODUCTION

In the 1950s Lauge-Hansen published his cadaveric studies of rotational ankle injuries using differing foot position and force direction combinations.^{1,2} Four common patterns were identified. As part of this work, posterior malleolus fractures were recognized as one component within a continuum of predictable rotational ankle injuries. This research was significant in revealing that posterior malleolus fractures are only one part of a larger ankle injury and that common ankle injury patterns exist.

Recently, there has been increasing recognition and interest in the association of tibial shaft fractures and ipsilateral ankle injuries.^{3–10} Identification of these articular ankle injuries is important for proper preoperative planning and appropriate postoperative physical therapy. The majority of publications to date have focused predominantly on the incidence of combined posterior malleolus and tibial shaft fractures. As posterior malleolus fractures typically represent only one component of a rotational ankle injury, we believe that tibial shaft fractures with concomitant ankle fractures are under appreciated. Additionally, although distal one-third spiral tibial shaft fractures have been shown to have a strong association with concomitant ankle fractures, no publication has explicitly quantified the predictive ability of this, or other, radiographic fracture patterns.^{8–10} Therefore, our hypothesis for this study is twofold: 1) the incidence of concomitant ankle injuries and tibial shaft fractures is underappreciated and is higher than previously reported; and 2) common radiographic characteristics such as location and pattern of the tibial and fibular shaft fractures exist that can quantitatively predict the presence or absence of an ankle injury.

PATIENTS AND METHODS

Eighty four patients with an operatively stabilized tibial shaft fracture were identified from the principal surgeon's surgical log book from January 2009 to November 2011. All 84 patients were initially included for analysis. Patients with evidence of prior ankle surgery with retained implants as well as those patients without a computed tomography (CT) scan of the tibia including the ankle were excluded from analysis. Non-acute injuries as well as pediatric and prisoner patients were also excluded.

A total of thirteen patients met exclusion criteria. Ten patients lacked a preoperative CT scan. An additional three patients were excluded for various reasons. One patient had a prior tibiotalar arthrodesis with resection of the distal fibula. Another patient had a prior open reduction and internal fixation of the distal fibula with a retained plate including two intact

syndesmotomic screws. The final patient had a chronically infected tibial non-union that was previously treated with external fixation at an outside institution. Therefore a total of 71 adult patients with an acute fracture of the tibial shaft and a complete set of radiographs and CT imaging were available for evaluation.

As part of our institution's standard preoperative evaluation all tibial shaft fracture patients have orthogonal tibia radiographs with supplemental radiographic views of the ankle and knee. A CT scan without iodinated contrast of the entire tibia that included the ankle was also obtained to assess for concomitant injuries. All CT scans were performed on a 64-slice scanner utilizing 1.25-mm axial slices.

Preoperative radiographs were retrospectively and independently evaluated by three upper-level orthopaedic surgery residents. Radiographs were scrutinized for tibia and fibula fracture location (proximal one-third, midshaft, or distal one-third), pattern, relationship between the two fractures (fibula fracture proximal, equal height or distal to the tibia fracture) and whether an ipsilateral ankle injury was present. The pattern of the tibia fractures were described using OTA classification system terminology such as spiral (42-A1), oblique (42-A2), transverse (42-A3), spiral wedge (42-B1), bending wedge (42-B2), fragmented wedge (42-B3), complex spiral (42-C1), segmental (42-C2) or complex irregular (42-C3).¹¹ For final statistical analysis spiral tibia fractures included all fracture patterns with a spiral component (42-A1, 42-B1, and 42-C1). Discrepancies between observers regarding any descriptive variables were resolved by consensus and the final attending musculoskeletal radiologist read.

Ankle injuries were determined by careful independent evaluation of all injury CT scans by the same observer group as the preoperative injury radiographs. Differences in reads were again settled by consensus. An ankle injury was judged to have occurred when any of the following were identified: an anterior inferior tibiofibular ligament (AITFL) injury equivalent represented by an avulsion fracture from the anterolateral aspect of the distal tibia; a posterior malleolus fracture; a medial malleolus fracture; or other fracture of the tibial plafond. All fibula fractures regardless of proximity to the ankle were considered a component of the tibial shaft fracture. This decision was made to decrease the uncertainty of whether a distal fibula fracture be considered an ankle injury or a component of the tibial shaft fracture.

Descriptive statistics were calculated in terms of means and standard deviations for continuous variables and frequencies and percentages for categorical variables. Following the descriptive analysis, inferential statistics were calculated to evaluate independent associations between fracture characteristics and the presence of an ankle injury. Group differences between tibia and fibula fracture characteristics with or without ipsilateral ankle injuries were evaluated using chi-square or Fisher's exact test. Odds ratios (OR) and their respective 95% confidence intervals (95% CI) were calculated to assess the magnitude and precision of their associations. Diagnostic statistics of sensitivity, specificity, positive and negative predictive values were calculated to evaluate the likelihood of ankle injury given a particular fracture pattern. Weighted kappa statistics were used to calculate inter-observer

reliability between readers. All analyses were done using SPSS version 19.0 (IBM SPSS Statistics Inc., Chicago, IL).

Approval for this study was obtained from our hospital's Institutional Review Board.

RESULTS

Seventy-one patients fulfilled the inclusion and exclusion criteria for the study. Thirty-seven (52.1%) patients were male and the average patient age at the time of injury was 42.4 years. A concomitant ipsilateral ankle fracture was found in 35 of the 71 tibial shaft fracture patients (49.3%). Of the 35 ankle injuries, an isolated posterior malleolus fracture occurred in 18 patients (51.4%), an isolated AITFL avulsion (Tillaux-Chaput) fracture was seen in 3 cases (8.6%), an isolated medial malleolus or an isolated tibial plafond fracture were each seen in 2 cases (5.7%) and the remaining 10 patients (28.6%) possessed two or more ankle injury markers – Figures 1 and 2. Injury ankle radiographs identified only 8 (22.9%) of the ipsilateral ankle fractures.

A spiral pattern was observed in 44 (62%) of the 71 tibia fractures. Fifty-five (77.5%) of the tibia fractures were located in the distal one-third of the tibial diaphysis. A spiral fibular fracture occurred in 24 of the 71 patients (33.8%) and a plurality of patients were observed to have their tibia and fibula fractures occur at the same height (35.2%). Table 1 summarizes the observed location and patterns of the tibia and fibula fractures in all 71 patients.

Univariate analysis of the patient data found that a spiral tibia fracture was significantly associated with the presence an ankle injury (OR 13.71; 95% CI 3.95–47.56; $p < 0.001$). Conversely, non-spiral tibial fracture patterns were significantly associated ($p < 0.001$) with an uninjured ipsilateral ankle (Table 2). Of the non-spiral patterns, an oblique tibial shaft fracture was the most statistically protective pattern (OR 0.16; 95% CI 0.03–0.78; $p = 0.02$).

Tibial fractures located in the distal one-third diaphysis were more likely to be significantly associated (OR 10.5; 95% CI 2.17–50.81; $p < 0.001$) with the presence of a concomitant ankle injury (Table 3). A midshaft tibia fracture location demonstrated a protective effect against ipsilateral ankle injuries (OR 0.13; 95% CI 0.03–0.65; $p = 0.012$).

A spiral pattern fibula fracture had a significant (OR 5.29; 95% CI 1.76–15.89; $p = 0.002$) association with an ipsilateral ankle fracture (Table 4). Patients with either a transverse pattern or absent fibula fracture were approximately 95% less likely to have an associated articular ankle fracture (OR 0.046; 95% CI 0.006–0.377; $p < 0.001$). Neither fibular fracture location nor the tibia and fibula fracture relationship had a statistically significant association with either the presence or absence of an ipsilateral articular ankle fracture (Table 5).

Based on the Landis and Koch¹² thresholds for interpreting weighted kappa coefficients, there was almost perfect inter-observer agreement in describing tibial fracture location ($\kappa = 0.87$), and substantial agreement for tibial fracture pattern ($\kappa = 0.74$), fibular fracture location ($\kappa = 0.78$) and in identifying an intra-articular ankle fracture ($\kappa = 0.78$). The categorization of fibular fracture patterns ($\kappa = 0.57$) had moderate inter-observer agreement.

In all, 31 of the 35 concomitant ankle injuries (88.6%) occurred in patients with a spiral pattern tibia fracture of the distal third diaphysis ($p < 0.001$). Recognition of a distal one-third spiral pattern tibia fractures had a diagnostic sensitivity of 88.6%, specificity of 63.9%, and positive and negative predictive values of 70.5% and 85.2%, respectively, for the presence of an ipsilateral ankle injury.

DISCUSSION

Our findings suggest that tibia and fibula fracture characteristics are predictive for either the presence or absence of concomitant articular ankle fractures. The association between an ipsilateral ankle injury and a specific tibial shaft fracture pattern and location has been previously reported. Bostman identified five (0.9%) ipsilateral fractures of either the lateral or posterior malleolus in 527 patients with a tibia shaft fracture.³ All of these concomitant ankle injuries were noted to occur with a spiral type tibia fracture pattern. Van der Werken and Zeegers observed that of 148 tibial shaft fractures all 17 (11.5%) patients with an ipsilateral posterior malleolus fracture had an obliquely oriented tibia fracture located in the distal half of the tibial diaphysis.⁴ Kukkonen et al found 18 (25%) posterior malleolus fractures in 72 patients with tibial shaft fractures.⁶ Of these patients, all had tibia fractures within the distal one-third diaphysis with 15 (83.3%) of these fractures demonstrating a spiral type tibial pattern. Steurmer and Steurmer identified an articular ankle injury in 43 of 214 patients (20.1%) with a tibial shaft fracture.⁷ All 43 tibia fractures were distal to the midshaft with 38 (88.4%) possessing a spiral pattern tibia fracture. Our results not only confirm the association between an ankle injury and a distal one-third tibia fracture location or a spiral tibia fracture pattern but also that transverse or absent fibula fractures as well as a midshaft tibia fracture location are not significantly associated with an ipsilateral ankle fracture.

Based on the aforementioned studies and their use of orthogonal radiographs, the incidence of tibial shaft fractures and concomitant ankle injuries has ranged from 0.9–25.0%. Two recent studies utilizing CT imaging to evaluate for concomitant ankle fractures demonstrated a higher incidence of injury ranging from 39–43%.^{8,10} However, both of these studies limited their investigation to distal one-third diaphyseal tibia fractures. Our results indicate that concomitant articular ankle injuries are more common than previously reported. We found that 49.3% (35/71) of all tibial shaft fractures and, more specifically, 60.0% (33/55) of distal one-third tibial shaft fractures had concomitant ankle injuries.

Recognition of a concomitant ankle fracture is important not only for preoperative planning but also for postoperative management. Georgiadis et al reported four patients that had significant posterior malleolus fracture fragment displacement intraoperatively while performing an intramedullary nailing for an ipsilateral tibial shaft fracture.¹³ None of their posterior malleolus fractures were recognized preoperatively. All four displaced fractures subsequently required either closed reduction and percutaneous screw fixation or open reduction and internal fixation. Preoperative recognition allows for pre-nailing fixation and therefore a lower likelihood of displacing the fragment and subsequent need for an open reduction. For non-posterior malleolus ankle fractures, such as a Tillaux-Chaput fracture fragment, no consensus exists as to whether internal fixation is required. However, since this

fracture represents a partially destabilizing injury to the syndesmosis, we believe fixation should be considered in cases with large articular fragments or obvious syndesmotic instability. As protocol, we stress every ankle after intramedullary fixation of tibial shaft fractures with ipsilateral intra-articular ankle injuries. Recognition of concomitant ankle injuries is important because it may alter the initiation of postoperative ankle range of motion or weight bearing.

Based on the results of our study, we recommend obtaining an ankle CT for all tibial shaft fracture patients with a distal one-third location or a spiral pattern. While recognition of a distal one-third spiral pattern tibia fracture is not completely predictive of a concomitant ankle fracture, nearly 90% (31/35) of all ankle injuries in our cohort occurred with this radiographic pattern. Only one ankle injury was observed in patients with either an isolated tibia fracture or those with a transverse fibula fracture pattern. Importantly, 14 (40.0%) of our ankle injury patients had fibula fractures proximal to the level of the tibial shaft fracture, thus it is advisable to visualize the entire fibula. After, if no fracture is identified or if it is a transverse pattern, we believe that further ankle imaging is not warranted. For all other tibia and fibula fracture patterns, the decision to obtain further imaging should be based on other clinical factors such as mechanism of injury and physical exam findings that were not addressed in our radiographic analysis.

There are limitations to our study. We used CT as the gold standard for diagnosing an intra-articular ankle fracture. A recent publication by Hou et al used radiographs, CT and MRI in diagnosing posterior malleolus fractures in spiral pattern tibial shaft fractures.⁹ Their imaging protocol consisted of obtaining ankle radiographs and if no posterior malleolus fracture was identified a CT scan of the ankle was performed. An MRI was then obtained if the CT demonstrated no posterior malleolus fracture. In seven cases, four posterior malleolus fractures were identified by MRI after an inconclusive CT scan. Therefore, although the incidence of concomitant ankle injuries that we observed was higher than that reported in prior studies the true incidence may actually be much greater if additional imaging modalities such as MRI are utilized. Additionally, our study did not investigate the association of clinical characteristics such as patient age, gender, mechanism of injury or patient comorbidities and a concomitant ipsilateral ankle injury in tibial shaft fracture patients. Further work in this regard is needed.

In summary, we found that concomitant ankle injuries are more prevalent than previously reported, especially in patients with distal one-third tibial shaft fractures. Common radiographic tibia and fibula fracture patterns exist to better predict the presence or absence of an ipsilateral articular ankle fracture. We found that recognition of a distal one-third spiral pattern tibial shaft fracture had 88.6% sensitivity and 63.9% specificity for the presence of an ankle injury. Lack of a fibula fracture, presence of a transverse fibula fracture or a tibial shaft fracture located in the midshaft were not associated with an ipsilateral articular ankle injury. Recognition of these specific tibial and fibular radiographic patterns can assist the treating surgeon in deciding if additional imaging such as CT or MRI is warranted, as identification of an ipsilateral ankle injury can be important in surgical planning and postoperative physical therapy.

Acknowledgments

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Image 1.

Anteroposterior (A) and lateral (B) radiographs of a distal one-third diaphyseal spiral (42-A1) tibia fracture demonstrating no obvious articular ankle fracture. Axial CT imaging reveals an AITFL avulsion fracture fragment (C) and non-displaced posterior malleolus fracture (D). Postoperative radiograph (E) demonstrates intramedullary fixation of the tibia and fibula with percutaneous 2.7 mm screws stabilizing the Tillaux-Chaput fragment and posterior malleolus fracture.

Image 2.

Anteroposterior (A) and lateral (B) radiographs of a distal one-third diaphyseal spiral (42-A1) tibia fracture. Axial (C) CT image demonstrates a nondisplaced posterior malleolus fracture. Postoperative radiograph (D) shows intramedullary tibia and fibula fixation with two percutaneous 2.7 mm screws stabilizing the posterior malleolus fracture fragment.

Table 1

Tibia Fracture Pattern	Patients	Fibular Fracture Pattern	Patients
Spiral (42-A1)	35	Spiral	24
Oblique (42-A2)	12	Oblique	12
Transverse (42-A3)	4	Transverse	10
Spiral Wedge (42-B1)	5	Butterfly	9
Bending Wedge (42-B2)	3	Comminuted	2
Fragmented Wedge (42-B3)	3	Segmental	9
Complex Spiral (42-C1)	4	None	5
Complex Segmental (42-C2)	4		
Complex Irregular (42-C3)	1		
Tibia Fracture Location		Fibular Fracture Location	
Proximal 1/3	1	Proximal to Tibia Fracture	24
Midshaft	13	Equal Height	25
Distal 1/3	55	Distal to Tibia Fracture	9
Segmental	2	Segmental	8
		None	5

Table 2

Tibial Fracture Pattern	No Ankle Injury		Ankle Injury		p-value
	N	%	N	%	
Spiral	13	36.1%	31	88.6%	<0.001
Non-Spiral	23	73.9%	4	11.4%	<0.001
-Oblique	10	27.8%	2	5.7%	0.024
-Transverse	4	11.1%	0	0.0%	0.115
-Bending wedge	2	5.6%	1	2.9%	0.999
-Fragmented wedge	3	8.3%	0	0.0%	0.239
-Segmental	3	8.3%	1	2.9%	0.614
-Comminuted	1	2.8%	0	0.0%	0.999

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Table 3

Tibial Fracture Location	No Ankle Injury		Ankle Injury		p-value
	N	%	N	%	
Distal 1/3	22	61.1%	33	94.3%	0.001
Mid-shaft	11	30.6%	2	5.7%	0.012
Proximal 1/3	1	2.8%	0	0.0%	0.999
Other (e.g. Segmental)	2	5.6%	0	0.0%	0.493

Table 4

Fibula Fracture Pattern	No Ankle Injury		Ankle Injury		p-value
	N	%	N	%	
None or Transverse	14	38.9%	1	2.9%	<0.001
Butterfly	5	13.9%	4	11.4%	0.999
Complex	1	2.8%	1	2.9%	0.999
Oblique	7	19.4%	5	14.3%	0.753
Segmental	3	8.3%	6	17.1%	0.307
Spiral	6	16.7%	18	51.4%	0.002

Table 5

Fibula Fracture Location	No Ankle Injury		Ankle Injury		p-value
	N	%	N	%	
Distal 1/3	13	41.9%	16	45.7%	0.758
Mid-shaft	5	16.1%	4	11.4%	0.724
Proximal 1/3	10	32.3%	9	25.7%	0.558
Other (e.g. Segmental)	3	9.7%	6	17.1%	0.484