INTRODUCTION

Intra-articular fractures often portend secondary osteoarthritis (OA), chronic pain, and decreased joint function. Clinical decision-making in treating complex articular injuries with comminution requires that a surgeon assess the relative injury severity of a given case. Until recently, there has been no practical way to objectively measure comminution and injury severity, preventing clinicians from compiling a body of literature and collective experience to guide care of these patients. A new CT-based methodology was recently developed to objectively quantify injury severity [1], exploiting the principle that mechanical energy is absorbed to create new free surface area in a brittle solid, the amount of energy required being proportional to the amount of inter-fragmentary surface area. This new objective metric has been shown to agree with experienced orthopaedic traumatologists’ subjective opinion of injury severity drawn from standard-of-care plain radiographs [2]. Since pre-existing versus de novo surfaces could both be present in fracture fragments, contralateral limb scans were required for that analysis to provide intact bone surface areas over a comparable distal segment of the patient’s tibia, for taring purposes. This presents a problem in the clinical setting, where CT scans of the intact contralateral limb are not routinely obtained during fracture evaluation.

In the present study, data collected previously from twenty-two different intact tibias (contralateral CT scans obtained as part of a fracture series) were used to establish an anthropometric database from which to draw taring surface areas for cases where an intact contralateral CT scan is unavailable.

METHODS

CT studies were obtained from twenty-two tibial pilon fracture cases. This research was carried out with the approval of our Institutional Review Board, and informed consent was obtained from all subjects. Scans of the unaffected contralateral limb spanned intact distal tibias of varying lengths. Bone free surface area measurements were extracted slice-by-slice from CT datasets using validated digital image analyses [3]. Cumulative areas were calculated by summing incremental surface areas over the length of the tibia scanned. The tibial length data, measured from the distal extent of the medial malleolus, were normalized to the overall length of each tibia, predicted from a patient’s height. Linear regression was performed upon these data (normalized length of tibial segment vs. cumulative area), producing an equation that predicted a tibia’s total surface area based upon the relative tibial length measured proximally from the medial malleolus.

The predicted cumulative area for each of the intact distal tibia was compared to the cumulative areas physically measured over the same lengths. Absolute and relative errors were calculated. As these data were intended to stratify injury severity, predicted interfragmentary surface areas (fractured area – intact area) were compared with those originally measured over lengths spanning 70 to 260 mm, measured along the tibia from the medial malleolus. These tibial lengths corresponded with normalized lengths from 12% to 54% of the entire tibia. Cumulative areas were linearly related to the normalized length along the distal tibia, (Figure 1; $R^2 = 0.93$).

Cumulative areas predicted from this linear regression showed good agreement with the cumulative areas previously measured, with absolute errors averaging 12% ($\pm10\%$) (Figure 2). As expected, calculated errors were largest for cases which extended the shortest distance into the diaphysis. The rank ordering of calculated vs. predicted interfragmentary surface areas agreed very well, with a concordance rate of 0.85.

DISCUSSION

We have shown that a distal tibia’s cumulative surface area increases proportionally to its normalized length, within the distal diaphyseal region. The developed predictive model based upon this finding allows taring of bone fragment surface areas with the pre-existing area, to yield interfragmentary surface area. This new objective metric has been shown to agree with experienced orthopaedic traumatologists’ subjective opinion of injury severity drawn from standard-of-care plain radiographs.

REFERENCES


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