A Predictive Model of Tibial Shaft Fracture Nonunion at the Time of Definitive Fixation

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Background/Purpose: A clinical tool that would allow surgeons to predict the likelihood of nonunion at the time of intramedullary nail (IMN) fixation of tibial shaft fractures could change the management of those at high risk of nonunion. Previous authors have explored possible factors influencing reoperation in tibial shaft fractures; however, no authors have developed a tibial shaft nonunion prediction model for the time of initial fixation for fractures treated with reamed IMNs (time zero). We posited that commonly collected data on patients, evaluation of the fracture and soft-tissue injury and postoperative films at the time of definitive IMN fixation, would allow us to extract statistically significant variables predictive of nonunion. Employing these variables we aimed to create a nonunion prediction model that would enable surgeons to predict nonunions in tibial shaft fractures at the time of IMN fixation.

Methods: Our final study group consisted of 382 adult patients treated with IMN for tibial shaft fractures (n = 56 progressed to nonunion, n = 326 healed without further intervention). All patients were followed to fracture healing or surgical intervention for nonunion and we excluded patients with adequate follow-up but indeterminate healing status. Importantly, no patients were included who had planned nonunion surgery, typically based on large fracture gap. We reviewed perioperative and follow-up radiographs, charts, and laboratory data. We defined nonunions as fractures expected to heal without further intervention that eventually, in the surgeon's judgment, required an additional operative intervention to ensure union. We collected patient data on 35 factors thought to contribute to delayed bone healing. Bivariate and multivariate regression techniques, as well as stepwise modeling approaches, were used to examine the relationship between variables available during the index hospitalization and subsequent nonunion. Over 26 variables were examined in the analysis but found to be insignificant. Nine factors were found to be significant.

Results: A multiple variable logistic regression model was developed that included 7 significant factors ($P < 0.05$ and odds ratio >2.0 in bivariate or multiple variable models): use of flap, open fractures, compartment syndrome, male gender, American Soceity of Anesthesiologists (ASA) classification, percent cortical contact, and chronic disease status (HIV/HepC/diabetes). Additionally, we found spiral fractures and low-energy mechanism predictive of union. Based on these factors we developed a model titled the Nonunion Risk Determination (NURD) score. The NURD score assigns 1 point per level for ASA and % cortical contact, 1 point for male gender, 2 points for open fracture, 3 points for chronic conditions, 4 points for compartment syndrome, and 5 points for requiring a flap. One point

each was subtracted from the score for spiral fractures or low-energy injury. Patients with a NURD score of 0 to 5 had a 1.72% chance of nonunion (4/232). Patients with a NURD score of 6 to 8 had a 22% chance of nonunion (22/101), Patients with a NURD score of 9 to 11 had a 42% chance of nonunion (13/31), and patients with a NURD score >12 had a 61% chance of nonunion (11/18).

Conclusion: We determined that a number of factors predict nonunions and can reliably be formed into a union prediction model to allow clinicians to determine very early in the treatment course which patients have a higher risk of nonunion. The ability to predict nonunion early in the patient's course may help guide patients and clinicians as to when patience (as union is likely) is the best approach and when interventions aimed at enhancing healing of the fracture through earlier surgical interventions may be reasonable options.

See pages 47 - 108 for financial disclosure information.