Factors Associated with Development of Nonunion or Delayed Healing Following Open Fracture: A Prospective Cohort Study of 736 Subjects

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Purpose: We sought to evaluate the factors associated with nonunion following open long bone fractures (humerus, radius/ulna, femur, tibia/fibula) including the relationship between time to initial surgical management. Secondarily, we examined factors associated with development of delayed healing.

Methods: Between 2001 and 2009, 736 subjects with 791 open fractures were enrolled in a prospective cohort study undertaken at 3 Level Itrauma centers and followed for 1 year. Demographics and injury information (Gustilo grade, fracture site, injury mechanism, timing of antibiotic administration, and initial surgery) were recorded. Subjects were evaluated postoperatively using standardized data forms until the fracture healed. Phone interviews were undertaken at 1 year. Nonunion was defined as unplanned surgical intervention after definitive wound closure or incomplete radiographic healing at 1 year post fracture. Delayed union was defined as lack of progression of radiographic healing at 2 consecutive postoperative visits or incomplete radiographic healing and ongoing clinical symptoms between 6 months and 1 year post fracture. Univariate logistic regression was undertaken for age, gender, time from injury to surgery, and antibiotic administration calculated in hours, Gustilo grade and fracture location (upper extremity, femur, tibia/fibula), presence of deep infection, smoking status, comorbid conditions, having associated injuries, multiple fractures, and receiving a transfusion. Two multivariate logistic regression models using nonunion and delayed union (yes/no) as dependent variables were developed.

Results: The mean age was 41.5 ± 17.1 years and 530 (72%) were male. Fractures occurred in motor vehicle accidents (n = 359 [49%]), falls (n = 230 [31%]), crush injuries (n =131 [18%]) and assaults (n = 16 [2%]). Tibia/fibula fractures were most common (n = 413 [52%]), followed by upper extremity (n = 285 [36%]) and femur (n = 93 [12%]) fractures. Follow-up (1 year interviews and/or clinical follow-up of >90 days) was completed by 695 (94%) subjects (746 fractures). Overall, 124 (17%) subjects had nonunions while 63 (10%) subjects experienced delayed healing. The median time to initial surgery was 9.0 hours(h) (interquartile range [IQR] 6.8, 12.0) for healed fractures and 8.3 h (IQR 6.3, 11.3) for nonunions (P = 0.36). The median time to surgery was 9.0 h (IQR 7.0, 12.5) for fractures without healing problems, and 8.0 h (IQR 5.5, 12.3) for those with delayed healing, respectively (P = 0.34). Multivariate logistic regression also showed no significant association between time to initial operative management and developing nonunion (odds ratio [OR] 0.97; 95% confidence interval [95% CI] 0.92, 1.01) or experiencing delayed healing (OR 0.96; 95%CI 0.90, 1.02). Deep infection (OR 12.75; 95% CI 6.1, 26.8), Gustilo grade 3A relative to grade 1 fractures (OR 2.5; 95% CI 1.3, 4.8) and smoking (OR 1.7; 95% CI 1.1, 2.8) retained a significant association with developing a non-union in the multivariate model. Deep infection (OR 4.3; 95% CI 1.2, 15.5) and Gustilo Grade 3B/C relative to grade 1 (OR 3.7; 95% CI 1.4, 9.4) fractures were significantly associated with delayed healing.

Conclusion: Development of nonunions or delayed healing is strongly associated with the presence of a deep infection and higher Gustilo grade fractures.

See pages 47 - 108 for financial disclosure information.