A11 A Transition Analysis of Pediatric Fracture Repair Stages

Nicholas V. Passalacqua, PhD, Western Carolina University, 101 McKee, Cullowhee, NC 28723; Michael W. Kenyhercz, PhD, Department of Defense POW/MIA Accounting Agency, 590 Moffet Street, Bldg 4077, Joint Base Pearl Harbor-Hickam, HI 96816; and Diana L. Messer, MS, 2873 Neil Avenue, Apt 452B, Columbus, OH 43202*

The goal of this presentation is to discuss the utility of transition analysis in the estimation of the age of pediatric healing fractures using radiographic images.

This presentation will impact the forensic science community by providing the ages of transition between stages of fracture repair from a large known pediatric sample, as measured by the date of injury to the date of radiographic imaging. This may have significant ramifications for investigations of child abuse and the interpretation of cases involving healing skeletal fractures.

Multiple fractures in various stages of healing are considered highly indicative evidence of physical child abuse.[1] The estimation of time since fracture, while complicated by factors such as age and anatomical location, has the potential to assist in the identification of physical abuse. In both forensic and clinical settings, a radiographic skeletal survey is generally performed to assess for occult and healing fractures, and this imaging is often the basis upon which an assessment of fracture healing is performed. Yet, despite a handful of studies examining pediatric fracture healing using radiographic images, the timing of fracture healing has yet to be fully understood.[2]

The goal of this project is to present the ages of transition between fracture repair stages for the interpretation and analysis of pediatric healing fractures. This study used data collected from a series of radiographs of lower limb and forearm bone fractures from 116 individuals within the age group most at risk for child physical abuse, individuals aged 0 to 5 years. Some individuals exhibited multiple fractures for a total of 185 forearm fractures and 107 lower leg fractures examined. These data were collected and previously examined by Malone.[3] This project reinvestigates this data with a different statistical approach: using transition analysis to determine mean ages and ranges of transition between fracture repair stages.

The original analyst (Malone) scored all radiographs within the following six-phase system: Stage 1 – No healing; Stage 2 – Granulation; Stage 3 – Callus; Stage 4 – Bridging; Stage 5 – Clinical Union; and, Stage 6 – Completion.[3] Using Analysis of Variance (ANVOA) tests, Malone found statistically significant differences in rates of healing between lower leg and forearm bones, with forearm bones healing faster, as well as differences in age, with individuals aged one year or less spending less time in Stage 1 than individuals aged two years or older.[3]

The present reanalysis uses these same data; however, the goal was to generate ages of transition between different fracture healing stages. To extend transition analysis for ordinal traits, a restricted cumulative probit regression was used. All analyses used the VGAM package in R.

Results found that for all transitions except one (Stage 4 to Stage 5), the mean age of forearm fractures was ahead of the mean age of the corresponding lower leg fractures. Further, when examining individuals aged one year or less versus individuals aged two years or more, there was no trend in mean-age transition timing, with neither group consistently ahead of or behind the other.

There was a great deal of overlap in transitions, especially between the first three stages. This overlap indicates that the present six-stage system does not provide a great deal of discriminating power between the current

morphological stage descriptions. Revising stage descriptions or generating new evaluative criteria for pediatric fracture healing has the potential to increase accuracy of fracture age estimates. For example, distinguishing between early features of fracture healing, such as subperiosteal new bone formation versus callus formation, has been suggested to improve interpretation of time since injury.[1] In addition, the effect of variables that influence rate of healing, such as age and anatomical location, should be further explored and considered in future work. Overall, transition analysis provides a more in-depth examination of pediatric fracture healing, allowing for broader interpretation when analyzing pediatric fractures.

Reference(s):

1. Walters M.M., Forbes P.W., Buonomo C., Kleinman P.K. (2014). Healing patterns of clavicular birth injuries as a guide to fracture dating in cases of possible infant abuse. *Pediatr Radiol.* 44(10):1224–1229.
2. Pickett T.A. (2015). The challenges of accurately estimating time of long bone injury in children. *J Forensic Legal Med.* 33:105-110.
3. Malone C.A., Sauer N.J., Fenton T.W. (2011). A Radiographic Assessment of Pediatric Fracture Healing and Time Since Injury. *J Forensic Sci.* 56(5):1123-1130.

Fracture, Healing, Child Abuse