A122 Rib Fractures: An Experimental Approach to Identifying Intrinsic Sources of Variability

Amanda M. Agnew, PhD, The Ohio State University, Columbus, OH 43210; Angela L. Harden, MA, The Ohio State University, Columbus, OH 43210; Akshara Sreedhar, BS, The Ohio State University, Columbus, OH 43210; John H. Bolte, PhD, The Ohio State University, Columbus, OH 43210; Yun-Seok Kang, PhD, The Ohio State University, Columbus, OH 43210*

Learning Overview: After attending this presentation, attendees will have an appreciation for interdisciplinary research in skeletal trauma analysis, specifically in human ribs. Attendees will learn how to conduct experimentally driven biomechanical validation of skeletal trauma for forensic anthropology purposes, and understand the importance of utilizing experimental data to support or challenge current assumptions.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by demonstrating the need for interdisciplinary biomechanical analyses of skeletal trauma in ribs. Increased understanding of intrinsic sources of variability in rib failure mechanisms will serve to improve skeletal trauma analyses in forensic anthropology.

Rib fractures occur frequently in motor vehicle crashes, accidents, and homicides and, therefore, are a high priority for skeletal trauma analysis in forensic anthropology.[1,2] Love and Symes provided strong justification for paying closer attention to rib fractures as they noted that on a large sample of adult ribs, the observable fractures did not necessarily follow predictable patterns.[3] Since these data were collected on forensic case studies, there is no way to know what the actual circumstances were that led to the fractures, and, therefore, details such as fracture mechanism as well as magnitude and direction of force cannot be substantiated. They challenge the forensic anthropology community to consider the influence of bone material and structure in interpreting its mechanical behavior. Others have also emphasized the critical role in understanding biomechanics in order to effectively assess skeletal trauma.[4] Some attempts have been made to induce human rib blunt force trauma in controlled settings, but these generally have included only small sample sizes that cannot satisfy *Daubert* criteria.[5] Nonetheless, more biomechanical experiments are critical to make advances in trauma analysis in forensic anthropology. Therefore, the goal of this study was to identify intrinsic sources of variability on rib response and fracture behavior. Additionally, common assumptions related to fracture outcomes were tested.

Dynamic (1–2m/s) experiments simulating a frontal blunt chest impact conducted in the laboratory on mid-level (5–7) human ribs from donors of all ages (4–108 years) and both sexes form the basis of this work (n=347). By creating a repeatable and tightly controlled experiment, all variance observed in how the rib responds to applied loading can be attributed to intrinsic bone properties. Three hundred ninety-one fractures occurred. In general, the most crucial finding from this research was that rib response in a simplified bending scenario may not be predictable. A rib's resistance to loading (measured by peak transmitted force) varied significantly by sex (students t-test, p<0.005), but was *not* successfully predicted by age (linear regression, R^2=7.3%). Wedge fracture types (23%) were *not* the most common as expected; instead simple fracture types (70%) occurred most frequently. Fracture type did have a significant relationship with age (Kruskal-Wallis, p<0.005), but *not* peak transmitted force (Kruskal-Wallis, p>0.005). Despite a consistent applied force among tests, the number of fractures that a rib sustained (a measure of injury severity) varied from zero (0.8%), one (81%), two (16.5%), or three (1.7%) and had no relationship with peak transmitted force (Kruskal-Wallis, p>0.005). Cross-sectional geometric properties were most influential in determining the rib's resistance to loading. For example, cortical area explained 55% of the variance in force (linear regression, p<0.005) and should be employed in interpretation of fractures by forensic anthropologists. This complex, hierarchical approach to finding mechanistic biological explanations for rib response to traumatic loading will be discussed in detail and will help to form a thorough understanding of why and how these injuries occur.

Reference(s):

1. Forman J. et al. Automobile injury trends in the contemporary fleet: Belted occupants in frontal collisions. *Traffic Injury Prevention*. 2019.
2. Hulse C.N., Stull K.E. Determining Common Skeletal Injury Locations Based on Manner of Death (MOD). *Proceedings of the American Academy of Forensic Sciences*, 70th Annual Scientific Meeting, Seattle, WA. 2018.
3. Love J.C., Symes S.A. Understanding rib fracture patterns: incomplete and buckle fractures. *Journal of Forensic Sciences* 2004.
4. Christensen A.M. et al. *Forensic Anthropology: Current Methods and Practice*. 1st ed. San Diego: Elsevier Inc.; 2014.
5. Daegling D.J., Warren M.W., Hotzman J.L., Self C.J. Structural analysis of human rib fracture and implications for forensic interpretation. *Journal of Forensic Sciences* 2008.

Blunt Force Trauma, Injury Biomechanics, Rib Fracture

*Presenting Author