H42 Evaluation of Rib Fracture Injury Modes and Biomechanics in Abused Infants

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After attending this presentation, attendees will understand the biomechanical principles underlying fracture patterns in the infant rib cage. Non-accidental rib fractures in children have been studied for decades, but the forensic application and interpretation of bone injuries is unclear due to variation in: (1) research methodology; and, (2) fracture visualization techniques in the radiographic, medical, and anthropological literature.

This presentation will impact the forensic science community by contributing to the knowledge of the biomechanics, modes of failure, and the patterns of injury in the infant rib cage, and the potential for the application of this knowledge in the diagnosis of rib fractures in cases of child abuse. Rib fractures in infants are often difficult to detect through radiographic images, so increased forensic anthropological knowledge on the subject can help anticipate Non-Accidental Trauma (NAT).

Rib fractures are pathognomonic for abuse in young children.[1] Violent squeezing, shaking, punching, or combinations of assaults are reported to predictably create failures in the posterior, anterior, and lateral arcs of the rib cage. Often, anterior-posterior compression is offered as an explanation of fractures to the rib heads and costotransverse processes as well as the anterior costochondral areas of infant chests; however, lateral fracture production in the chest remains unclear in the literature.[2] Many researchers include lateral arc fractures as part of the same anterior/posterior bending failure associated with shaking and compressive injuries.

To address this discrepancy in the literature, fracture patterns were observed in ten NAT infant rib fractures. Rib fractures were recognized at autopsy, removed, and examined in a dry state with a stereomicroscope. Bone failures were assessed in terms of tension and compression.

Posterior and anterior arc fractures are by far the most observed; lateral arc fractures were rare, despite their common mention in the literature. Tension failure in the rib heads occur anteriorly as the rib neck is levered over the transverse process; failure first occurs in the area where the rib head is thin yet firmly attached to the vertebra body. The same bending motion may also create fractures in the area of the transverse process articulation. The latter fractures react like bending long bones diaphyses, where bone is highly resistant in compression due to thickened cortical bone, so failure occurs initially in tension on the internal rib surface.

Anterior rib fractures are a dissimilar reaction of the chest to posterior rib fractures. The cortical bone of the front rib is thin and trabecular bone is prominent. The structure is similar to bone metaphyses and epiphyses, where bone is weak in compression but capable of repeated trauma. Buckle fractures occur in front rib shafts and damages to costochondral junctions are most often observed in circumstances of anterior/posterior compression where flexible bone fails initially in compression.

The commonly described lateral arc failure scenario would suggest failure with compression internally and tension externally; however, if midshaft rib failures are more commonly associated with direct impacts, the biomechanics of failure should demonstrate the opposite direction of bending (i.e., an impact to lateral ribs would initially fail internally in tension). This lateral scenario appears to be a likely consequence in the non-accidental bone injury cases observed.

The recognition of tension/compression bone failure confirms the mode of bone bending and goes beyond spatial recognition and stereotypic explanations for rib fractures. Assessing skeletal injuries from a biomechanical perspective reveals specific relationships of bone injuries and conceivably facilitates the evolution of bone trauma interpretation as a scientific discipline. Therefore, fresh and healing fractures may reveal additional information concerning skeletal element failure. In the current study, lateral rib fractures appear to be rare and not a result of anterior-posterior squeezing.

References:

1. Kleinman PK. Schlesinger, AE. Mechanical factors associated with posterior rib fractures; laboratory and case studies. *Pediatr Radiol*; 1997; 27: 87-91.
2. Bilo RAC, Robben SGF, van Rijn RR. 2011. *Forensic Aspects of Paediatric Fractures. Differentiating Accidental Trauma from Child Abuse*. 2011; 49-65; Springer-Verlag.

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