H31 A Return to the Basic Principles of Biomechanics to Interpret Blunt Force Trauma in Long Bones

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After attending this presentation, attendees will gain knowledge on basic biomechanical theories necessary to interpret blunt force injury in long bones.

This presentation will impact the forensic science community in addressing two common problems associated with fracture interpretation of blunt force injuries in long bones. The recognition and examination of the failure mode of bone (compression/tension/shear) is often lacking in trauma analysis and is reflected in common errors made in the field. One misconception assumes the location and direction of bone failure is directly related to the point of impact. Another is that analyses often concentrate on a single broken bone as opposed to evaluating the complete trauma pattern on the body.

Five types of external loading conditions are commonly described with long bone fractures:–compression, tension, shear, bending, and torsion. These external loading conditions are typically associated with recognizable fracture patterns, namely transverse, oblique, oblique transverse, butterfly, and spiral fractures. Fenton et al., as a reaction to recent anthropology literature, examined the association between these external loading conditions and resulting fracture patterns and demonstrated that blunt fracture patterns, particularly butterfly fractures, can be used to determine the point of impact on experimentally broken bones.[1] They further suggested four common fracture patterns are recognized: incomplete butterfly fractures (tension wedges); transverse fractures (initiation); failure angle shifts of 45 degrees; and breakaway spurs. Fracture pattern "categories" linked to external loading conditions may lead an expert to a factual diagnosis regarding the point of impact, but the failure mode of the material (tension/compression/shear) is ignored and, as such, the forensic scientist may misinterpret the external loading conditions and/or the point-of-impact.

"Point-of-impact" is commonly used to describe and to interpret the wing of a butterfly fracture. Yet without soft tissue or a corresponding tool mark on bone, biomechanically, a butterfly fracture only indicates the direction of bending failure.[2] The area of failure in a bone shaft and the location and direction of impact are not one and the same concept. In any tubular bone, the failure mode only provides information as to the direction in which the bone bends (directionality) and to an anatomical weak point of the shaft. Furthermore, the failure modes involved in bending bone (tension, shear, and compression) are not mutually exclusive; thus, any failure mode can be used to establish bending direction and failure in long bones.[2] Therefore, a long bone fracture is attributed to the biomechanics of fracture production and not to a reconstructed fracture pattern or to a known impact site.[3] Despite the findings of three-point impacts in the laboratory, real-world scenarios such as automotive collisions, falls from heights, or beatings may result in long bone fractures via a variety of external loading conditions. Thus, a total body trauma pattern must be considered when examining and interpreting any fracture.

Complicated fracture patterns may be unraveled when a proper stress analysis of bone is conducted to determine stress/strain distributions as well as external loading and boundary conditions; all fractured surfaces are macro- and microscopically examined; and a complete analysis of body trauma is performed. For an accurate diagnosis, these steps need to supersede specific fracture interpretations. In this presentation, three cases of blunt traumatic injury to bone will be illustrated. While the reconstructed bone failure patterns are clear in each case, closer examination of biomechanics, along with knowledge of the overall trauma pattern, reveals clues as to the mechanism of failure. With the use of these cases, the above-mentioned pitfalls of trauma analysis within tubular bone are addressed and clarified.

Forensic anthropologists and pathologists are encouraged to closely examine bone failure at the materials level; to observe stress risers and resistors involved in a bone injury; to consult biomechanical engineers to evaluate loading conditions and internal stress distribution in long bones; to correlate fracture morphology and failure mode evidence in the fracture pattern; and to avoid over-reaching assumptions and predictions regarding impact sites. The proposed approach is designed to reduce error in our contributions to cause and manner of death and to avoid the negative repercussions associated with an inaccurate trauma analysis.

References:

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2. Symes SA, L'Abbé EN, Chapman EN, Wolff I, Dirkmaat DC. Interpreting traumatic injury from bone in medicolegal investigations. In: Dirkmaat DC, editor. A companion to forensic anthropology. London: Wiley-Blackwell, 2012;540-90.

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