H98 Bone-Breaking Rules: A Report of Six Fracture Mechanism-of-Injury Axioms Developed From Experimental Impact Testing

Tyler A. Kress, PhD, BEST Engineering, 2312 Craig Cove Road, Knoxville, TN 37919; David J. Porta, PhD, Bellarmine University, Department of Biology, 2001 Newburg Road, Louisville, KY 40205; Anne M. Kroman, MA, University of Tennessee, Department of Anthropology, Knoxville, TN 37996; and Bryce O. Anderson, PhD, BEST Engineering, 2312 Craig Cove, Knoxville, TN 37919*

After attending this presentation, attendees will learn about six widely applicable bone fracture axioms, useful in a forensic setting investigation and reconstruction.

This presentation will impact the forensic community and/or humanity by helping to further the understanding of bone fracture patterns and mechanisms of injury.

Understanding relationships among engineering inputs (i.e. loading characteristics) as they relate to anatomical outputs (i.e. fracture) of human long bones and the human head is very important for biomedical engineers, physical anthropologists, pathologists, and other forensic professionals. Developing widely-applicable bone fracture axioms is useful for forensic analyses. Therefore, a characterization of injury mechanisms of certain bones (i.e., in the extremities and the skull) in response to impact loading are delineated in the form of succinctly stated rules.

Real-life pedestrian, motor vehicle collision, and violent impact trauma scenarios were modeled by dynamically loading 583 human cadaver specimens, including intact extremities, heads, and bare long bones (numerous porcine bones were also used). A cart/guide-rail impacting system and a drop tower apparatus were used for most of the tests (the ballistic tests were done with a real handgun and a real rifle in bench rest position). Parametric work was conducted that varied numerous test variables such as loading direction, impact velocity, and impactor geometry.

The data support findings that may be reported in the form of succinct *Bone-breaking Rules*. *Rules 1, 2, 3, and 5* are based on 558 bone fracture tests using intact legs and bare long bones; *Rule 4* is based on 25 human head impact tests; *Rule 6* is based on numerous porcine tests.

1) ***The point of a wedge is opposite of the point of impact.*** The wedge fracture pattern can definitively be used as an indicator of the direction of impact. A common fracture pattern for long bones is the wedge fracture (also referred to as butterfly or delta fracture). Wedge fractures of long bones clearly originate at a location directly opposite of the point of impact and the wedge segment radiates back through the bone. Long bones fail in tension when they are loaded in a transverse fashion and a resultant wedge will "point" in the direction of the movement of the impactor.

2) ***Comminution does not necessarily mean "high speed" and/or crushing.*** This is somewhat of a unique observation because it has been commonly reported that butterfly wedges result only from high-speed impacts. Also, comminuted fractures often occur without entrapment (crushing injury). At approximately 7 m/s the inertial restraint of the tibia from just the mass of the thigh and foot is sufficient to result in comminuted fractures.

3) ***Spiral fractures only appear when bones are subjected to torsional loads.*** The spiral fracture is commonly mistaken for an oblique fracture and often the terms are used interchangeably or combined. The literature is replete with phrases such as "spiral oblique fracture". There is clearly a difference between the spiral and oblique fracture patterns. The definitive feature for distinguishing a spiral fracture is the vertical fracture that connects the proximal and distal portions of the helical aspect. To interpret which direction the bone was twisted, an examiner can note which direction the spiral runs around the bone; that direction is the same direction the torque was applied to that end of the bone.

4) ***Fractures of the skull radiate directly from the point of impact.*** In fracture pattern interpretations, some researchers have suggested that the point of impact is at a location other than the interface between the impacting object and the skull. This is not correct, i.e. the fracture epicenter is at the location of contact by the impacting object. Bone is brittle and the only exception noted with respect to fracture initiation being somewhere other than the interface of the bone and the impacting object is that of long bones when tension failure occurs.

5) ***Impacted fractures indicate relatively pure axial loading.*** However, an axial load can also give rise to bending fractures. If a fracture of a long bone is labeled as an impacted fracture, then the diaphysis of the bone experienced relatively pure longitudinal compression. If the compression (or axial load) gets "off-center", the resulting failure mechanism can be bending.

6) ***The degree of plastic deformation relates to the speed of impact.*** This is almost a restatement of viscoelasticity. This rule involves a comparison of ballistic speed versus other speeds (such as pedestrian/vehicle collisions). What is particularly important about this rule is that it is not just applicable to

 ** Presenting Author*

mechanical properties of bone but it is also applicable to fracture behavior. This is easily illustrated through forensic reconstruction of ballistically-damaged bones (which express minimal plastic deformation) in comparison to lower-speed blunt trauma impacts which demonstrate a higher degree of warping and plastic deformation. Note, too, that bones are not damaged from soft tissue pressure waves from typical small arms, and that bones will exhibit a temporary cavity when actually struck by a projectile.

Bone Trauma, Mechanisms of Injury, Impact Biomechanics