C32 Low-Energy Bone Fractures

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The goals of this presentation are to increase awareness of low-energy bone fractures, review the factors potentially responsible for reducing fracture threshold, and facilitate reconciliation of low-energy events that will result in ostensibly disproportionate bone fractures.

This presentation will impact the forensic science community by reviewing the factors that reduce fracture thresholds and thereby assist the forensic investigator to reconcile seeming discrepancies between low-energy events and bone fractures. Forces calculated from reconstruction of low-velocity accidents or otherwise atraumatic incidents may appear incommensurately small compared to the accompanying human injuries. This can generate uncertainties regarding the reconstruction mechanics or incident events. Fractures of the appendicular skeleton accompanying low-energy incidents are becoming more prevalent and thus gaining greater attention.

The accident reconstructionist/human injury analyst quantifies event kinetics, calculates associated impact forces, and links these forces to the resulting injury by using probabilistic methods. Although the magnitudes of the event-related forces are generally proportional to the degree of injury, the relationship between force and injury in low-energy events is often nonlinear. Such disparities can lead to uncertainties regarding the validity of the reconstruction, inclusiveness of the events considered, or skill of the investigator.

These disparities may be partially resolved by considering the factors affecting bone's mechanical competence. Bone is both a calcium-ion reservoir and a dynamic mechanical load-bearing organ. These vital functions are enabled by a time-varying composite biomaterial with complex micro and macro skeletal structures. The mechanical competence of normal healthy bone is optimal; material or structural deviations from normal commonly result in compromised load-bearing capabilities and increased low-energy fracture susceptibility.

Bone material abnormalities can arise from inherited defects in bone metabolism that result in subnormal fracture resistance. Bone mass abnormalities are linked to sex hormone inadequacies (hypogonadism) or, more commonly, loss of estrogen in post-menopausal (natural or surgically-induced) women. Estrogen loss precedes the well-known (osteoporosis) rapid loss of bone mass due to supra-normal bone turnover. Antiresorptive drug therapies reduce turnover and bone loss, but new evidence suggests that long-term use of these drugs can adversely alter fracture resistance. This topic is currently under investigation due to the tens of millions with osteoporosis (growing ranks of aging baby boomers) and the widespread use of these drugs.

Lifestyle changes can also predispose bone to low-energy fracture. Bone mass increases rapidly during adolescence, peaks somewhere in the late-teens to mid-30s, then slowly declines throughout life. Evidence exists that exercise-induced bone mass increases persist to some degree throughout life, and conversely, inadequate skeletal loading during development prevents attainment of peak bone mass. Adults so affected begin "withdrawing bone" from a smaller "bone mass nest egg" and critical fracture thresholds are thus reached sooner.

Dietary insufficiencies also conspire against fracture resistance. Bone is a composite material made chiefly of protein and mineral (calcium hydroxyapatite). Current preferences for carbonated beverages instead of milk are thought responsible for deficiencies in calcium intake. Limiting sunlight exposure inhibits production of the active form of vitamin-D (essential for calcium absorption from the gut) and thus exacerbates the lack of calcium. Mild cases of vitamin-D deficiency are common even in otherwise well-nourished adults. Bone mass, critical for fracture resistance, cannot be gained or maintained in the absence of essential building materials.

Bone fractures are also appearing in response to low-energy events in young middle-aged pre-menopausal women with otherwise normal bone mass. The etiology of these fractures is unknown, but recent findings suggest structural defects in bone's protein component, notably abnormal collagen crosslinking.

Reconciliation of the force levels produced by low-energy events with resulting bone fractures requires a more thorough approach to understand this causal relationship. References linking force amplitudes with fractures offer data from populations, but understanding an individual's bone fracture threshold requires additional consideration of the particular material and structural aspects of the involved bone. This begins with a complete patient history, including prior surgeries, injuries, and medications. Non-invasive diagnostic tests quantifying the amount (bone mineral density) and current changes (biomarker assessments) in bone mass are also helpful and may exist in the subject's medical records. Bone biopsies are exceptionally useful, when available, and can provide the basis for a quantitative assessment of bone material composition and load-bearing structure. The forensic investigator should consider these and other factors to help understand the relationship between low-energy events, the accompanying forces, and the resulting bone injuries.

Human Injury, Injury Analyses, Accident Reconstruction

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