C4 Low-Energy Bone Fractures: Part II

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The goal of this presentation is to review the factors associated with reduced bone toughness and facilitate reconciliation of low-amplitude forces to seemingly disproportionate bone fractures.

This presentation will impact the forensic science communtiy by showig forces calculated from reconstruction of low-velocity accidents or otherwise atraumatic incidents may appear incommensurate with the accompanying human injuries. This can lead to uncertainties regarding reconstruction mechanics or incident events. Bone fractures accompanying low-energy incidents are becoming more prevalent and are gaining greater attention. This presentation will review the factors linked with reduced bone fracture thresholds and thereby help the forensic investigator reconcile seeming incongruities between low-energy events, reconstruction derived forces, and accompanying bone fractures.

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, accuracy/inclusiveness of the events considered, or skill of the investigator.

These disparities may be partially resolved by considering the factors governing bones' fracture resistance. 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 biologically governed micro and macro structures. The mechanical competence of normal healthy bone is optimal; material or structural departures from normal will commonly result in compromised load-bearing capabilities and increased fracture susceptibility.

Bone mass, critical for fracture resistance, cannot be gained or maintained in the absence of essential building materials. Bone is a composite material made chiefly of protein (collagen) and mineral (calcium hydroxyapatite). Contemporary diets foretell reduced bone toughness because the "Pepsi® generation" eschews milk for carbonated beverages. Dietary calcium intake has thus been notably deficient.

Bone mass abnormalities are also linked to sex hormone inadequacies, most commonly evident in post-menopausal women. Menopause related estrogen loss precedes rapid bone loss due to high bone turnover characteristic of osteoporosis. Anti-osteoporosis drugs reduce turnover and bone loss, but new evidence suggests that their long-term use reduces fracture resistance due to oversuppressed turnover and unrepaired bone microdamage. This is important for America's aging baby boomer population and the four million adults currently taking anti-osteoporosis drugs.

Lifestyle changes also predispose bone to low-energy fracture. Bone mass increases rapidly during adolescence, peaks late in life's second to mid-third decade, then slowly declines. Exercise-induced bone mass increases during adolescence may persist (to a reduced degree) throughout life; however, inadequate skeletal loading during adolescence prevents attainment of peak bone mass. Persistent inactivity in adulthood results in "withdrawing bone" from a smaller "bone mass nest egg" and critical fracture thresholds are therefore achieved earlier. Reducing sunlight exposure also reduces blood levels of the active form of Vitamin D, critical for calcium absorption in the gastrointestinal tract, thereby further exacerbating calcium deficiencies. Current studies show mild Vitamin D deficiencies even in otherwise well-nourished adults. Extreme cases of Vitamin-D deficiency are associated with loss of bone stiffness and markedly increased fragility.

Clinical reports note the growing incidence of low-energy bone fractures in younger middle-aged pre-menopausal women with otherwise normal diets, sufficient exercise, and normal bone mass. The etiology of these fractures is unclear, but recent findings suggest abnormal collagen crosslinking that may be heritable. This is currently a field of active investigation.

To summarize, reconciliation of low-amplitude forces accompanying seemingly atraumatic incidents with resulting bone fractures requires detailed consideration of the material and structural aspects of the involved bone. This begins with a patient history, including prior diet, history, surgeries, lifestyle, and medications. Noninvasive diagnostic tests assessing bone quantity are essential; needed information may exist in current medical records. Missing information may be obtained from various assessments performed on bone samples, i.e., bone biopsies to quantify: bone structure, material composition, and microdamage. The forensic investigator should consider these and other factors to help understand the relationship between low-energy events and accompanying, but seemingly disparate, bone fractures.

Low-Energy, Bone Fracture, Bone Quality

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