A119 Is Quantitative Ultrasound (QUS) a Useful Tool for Evaluating the Mechanical Properties of Infant Cortical Bone?

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The goal of this presentation is to compare Speed Of Sound (SOS) values measured from pediatric bone with mechanical properties derived from tibial specimens to determine whether SOS reflects bone strength.

This presentation will impact the forensic science community by introducing pilot data for biomechanical properties of infant bone, which is absent from clinical and anthropological literature, and by discussing the assessment of QUS as a technique for evaluating infant bone quality.

In pediatric cases with suspected non-accidental injury, bone quality/strength is of prime interest. Defense attorneys often argue that skeletal injuries in these cases could result from normal handling due to inherent bone fragility caused by various non-confirmed diagnoses (i.e., temporary brittle bone disease, osteogenesis imperfecta, etc.). These arguments are disputed using medical findings and opinions of expert witnesses; however, opinions regarding bone quality and fracture susceptibility are typically based on qualitative assessments. Currently, there are no validated quantitative methods available for the assessment of infant bone quality; however, QUS is a validated technique for osteoporosis diagnosis in adults.

This research tests the efficacy of QUS in assessing infant bone quality through the comparison of tibial SOS values with the mechanical properties of tibial bone planks. It was hypothesized that SOS would exhibit a significant positive relationship to ultimate strength and elastic modulus and a significant negative relationship to plastic toughness. These hypotheses were deduced from two research-based assertions: (1) bone mineralization increases with age in children and SOS is positively correlated with mineralization in adult studies; and, (2) degree of mineralization affects the mechanical behavior of bone.

This study sample consists of 19 decedents ranging from 0 to 10 months of age. For each individual, SOS was measured on the antero-medial aspect of the tibial midshaft with QUS. Subsequently, a 10mm x 2mm section of bone was excised from the tibia using a Dremel® tool, placed in 70% ethanol, and refrigerated at 3°C-4°C. In preparation for mechanical testing, the specimens were cut into planks using an IsoMet® wafering saw, rehydrated in phosphate-buffered saline prior to mechanical testing, and tested wet at room temperature. The specimens were loaded in 3-point bending according to the following protocol: specimens were preloaded to 0.2N for two seconds and loaded at a displacement rate of 0.1mm/s until fracture or until a strain of 20% was reached. Load and displacement data were captured at a rate of 40Hz using Bluehill® software. Statistical analyses were performed using SPSS 22.

Results reveal no significant associations between SOS and the intrinsic material properties of the tibial specimens. Age was significantly correlated with ultimate strength ($r = 0.48$, $p = .036$) and elastic modulus ($r_S = 0.48$, $p = .038$). There was no significant correlation between SOS and age in the pooled sample; however, SOS was significantly correlated with age ($r = 0.62$, $p = .017$) after removing infants less than one month of age from the analysis.

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Results indicate a complex relationship between age and SOS. SOS did not significantly correlate with age during the first month of life nor did it significantly correlate with biomechanical variables. During the first month of life, there was notable variation in SOS, which was likely related to variability in bone composition and porosity. In contrast, the comparison between age and biomechanical factors performed as expected. Cortical bone stiffness increases with age along with the amount of stress the cortical bone could withstand prior to failure. Owing to the bone elasticity, mechanical loading to the point of fracture was difficult to achieve in some specimens requiring the predetermined total strain (20%) value as the failure point. Potential explanations for these findings include: small sample size; samples with substantial subperiosteal new bone formation, which may influence the acoustic impedance of SOS and the mechanical behavior (i.e., more crushing than bending); and the endosteal trabeculae were trimmed from the second batch, which was not performed on the first batch. The presence of trabeculae may have introduced noise into the biomechanical data. Although the hypotheses were not accepted, these finding are preliminary. With additional data, a more definitive statement regarding the relationship between SOS and biomechanical properties in infants can be presented.

Speed of Sound (SOS), Biomechanical Properties, Infant Cortical Bone

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