A130 Need a New Headspace? A Semi-Automated Volumetric Approach for Subadult Age Estimation Using the Spheno-Occipital Synchondrosis

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After attending this presentation, attendees will appreciate the advantages and principal processes of applying a semi-automated growth plate measurement protocol based on voxelization and volume calculation to quantify the tissue composition of irregular skeletal regions such as the spheno-occipital synchondrosis.

This presentation will impact the forensic science community by providing an attractive alternative to traditional phase-based age-estimation methods by introducing quantitative methodologies to measure material density distributions embedded in cross-sectional tomography data.

Due to the high probability of recovering the skull in anthropological casework, the spheno-occipital synchondrosis is frequently used as an indicator of subadult age, as it constitutes the last site in the cranium to terminate growth. Disparity regarding the reported age of complete synchondrosis fusion is evident in current literature, possibly attributed to inconsistencies in research design and visualization medium. Consequently, the reliability of ordered age-phase strategies employed in qualitative assessment may be questioned due to: (1) ambiguity in phase descriptions; (2) variation in the number of stages; and, (3) significant overlap in age ranges between consecutive phases.

Volumetric analysis using automated segmentation algorithms constitutes standard practice in medical science for monitoring skeletal toxicity and neurological assessment of intracranial pathologies, where voxelization and volume calculation are imperative for diagnostic and treatment decisions. A semi-automated method for volumetric measurement was developed based on differential voxel intensity values of the Hounsfield scale (HU) that discriminate material composition of the spheno-occipital synchondrosis in Computed Tomography (CT) orthoslices. Manual segmentation was conducted to: (1) create a sub-volume of the original Digital Imaging and Communications in Medicine (DICOM) stack; and, (2) isolate the joint space to create a binary tissue classification mask. MATLAB® commands were written to eliminate voxels exceeding the mask and to produce a histogram of intensity values for each individual based on voxel-clustering of biological material. Intensity values were correlated to specific tissue types (i.e., hyaline vs. calcified cartilage) using Bayesian probabilistic analysis, followed by tissue volume calculations using the voxel count and size. Linear synchondrosal measurements were conducted to eliminate the effect of size. The protocol was applied to cranial CT data from The Skeletal Biology and Forensic Anthropology Research Osteological Database on 169 Australian individuals aged birth to 18 years to generate preliminary density histograms for age estimation using mixture modeling.[1] Cumulative Density Functions (CDF) for key age ranges were calculated using a sub-sample of this data, with age estimates of remaining individuals based on agreement with the conceptualized CDFs using the Kolmogorov-Smirnov test. Non-linear regression with variance modeling was utilized to formulate predictive algorithms, which will be subject to validation on an independent sample acquired from The Royal Children's Hospital, Brisbane and disclosed in February 2015.

Preliminary results demonstrate a gradual decline in standardized cartilaginous volume of the spheno-occipital synchondrosis until 16.3 and 13.8 years in males and females, respectively, which constitutes the age of complete fusion in this population. In the neonate, mean cartilaginous volume in males was 461.67±49.28mm^3 compared to 299.35±32.76mm^3 in females; with males exhibiting significantly greater volumes (P<0.05) across all age intervals until 14 years, which correlates with delayed closure of the synchondrosis. Males exhibit a consistent linear decline in volume with age, while the rate of decline accelerates after eight years in females. Height and width variables demonstrate expansion through adolescence, the most prominent increase observed between birth and four years during which time chondrocyte proliferation and matrix production occur rapidly. Proceeding this period, endochondral ossification commences at the superolateral borders, causing a reduction in the gradient of growth. Significantly, voxel cluster distributions successfully discriminate tissue changes with increasing age, with neonates exhibiting a cluster peak corresponding to the density of fibrous tissue. At five years of age, the highest proportion of intensity values denote hyaline cartilage in contrast to cluster peaks at 150-250HU at 14 years

of age, emphasizing significant cartilage calcification prior to complete ossification (+250HU) at 16 years in Queensland males. New mathematical models, validated on a large, modern Australian population, will be introduced as a tool for methodological refinement, providing a robust alternative or adjunct to current subadult aging methods. The utility of the proposed methodological approach to epiphyseal growth plates of the post-cranial skeleton for multi-factorial age estimation will also be discussed.

Reference:

1. Lottering N, MacGregor DM, Barry MD, Reynolds MS, Gregory LS (2014) Introducing standardized protocols for anthropological measurement of virtual subadult crania using computed tomography. *J Forensic Rad Imag* 2(1): 34-8.

Subadult Age Estimation, Volumetric Analysis, Spheno-Occipital Synchondrosis