Age estimation in adolescents and young adults using MRI data of the manubrium

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Target audience: Researchers interested in MRI applied to skeletal age estimation.

Purpose: Forensic age estimation in adolescents and young adults has become important to verify age in legal proceedings like majority age determination of asylum seekers or prevention of fraud in junior level sports competitions. Specifically, skeletal age estimation in the manubrium has been analyzed in previous works all indicating that there is significant, reproducible change in shape from fetal development until young adulthood[1,2], related to growth development and maturation. All existing studies are based on histology, CT or X-ray images, thus the use of MRI is of great interest due to the lack of ionizing radiation. In this study, manubria from adolescents and young adults acquired by MRI were characterized with volume, surface between specific landmark points, and shape changes and the variation of these parameters with age was analyzed.

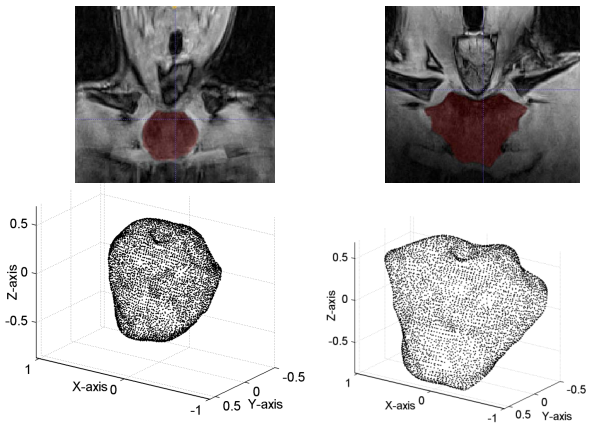

Fig. 1: Segmentation of T1 weighted coronal slices of the manubrium from a 15 year (left) and a 23 year (right) old male patients (top line) and corresponding simulated age-dependent change of manubrium shape using PCA (bottom line).

Methods: 1) MR measurements: 42 male subjects aged from 13 to 24 years were examined using a clinical 3.0T scanner (Tim Trio, Siemens AG, Germany). Images of the manubrium were acquired in supine position with a neck coil (Siemens AG, Germany). T1 weighted images were obtained using a 3D VIBE sequence with water excitation (TR/TE=9.77/3.72 ms, FOV=240 mm, matrix 168×192, voxel size 0.9×0.9×0.9 mm^3). To avoid pulsation artifacts from the heart and vessels, saturation bands were applied in caudal and posterior position of the 3D block. 2) Manubrium characterization: From the acquired T1 weighted images and using ITKSnap software, both, specific landmarks were manually defined to characterize a manubrium's surface, and volume segmentation was manually performed (Fig. 1, upper row). From the manually segmented manubria, 3D meshes were created and pre-processed using the MeshLab software to smooth the meshes, reduce their number of triangles and roughly align them for registration by translation into their centers of gravity. For registration we selected a base mesh which was non-rigidly registered to all other meshes[3] (Fig. 2). We then performed a Principal Component Analysis (PCA) on the set of registered meshes using corresponding 3D points as input. 3) Manubrium and age relationship: As a last step correlation of volume, surface and the strongest PCA model parameter (i.e., the parameter explaining most of the shape variance in the training data) with age was explored and the influence of patient height on the acquired parameters was investigated.

Results and discussion: The correlation of manubrium volume and surface with age was statistically significant (R^2_s=0.446; R^2_v=0.487), improving slightly when including the height of the patient into the analysis ($R^2_{s/h}$=0.485; $R^2_{v/h}$=0.515). Additionally, the strongest principal component also showed a significant correlation with age (R^2_{PCA}=0.485). The three variables volume, surface and PCA parameter indicated similar variation with age (Fig. 3). However, only the PCA result allows for directly simulating age-related shape change (Fig. 1, bottom row) and an inclusion of more components may still increase the correlation coefficient.

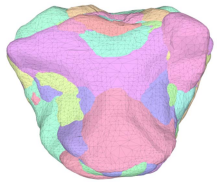

Fig. 2: Representation of all 42 manubrium meshes non-rigidly registered to a base mesh.

Conclusion: The presented results indicate that age estimation from MRI data of manubria is feasible. Non-linear simulation of shape change of the manubrium with age is a new tool which will help understanding the influence of different parameters like ossification centers[4] in the developing manubrium shape, while manual volume and surface segmentation suffers from observer variability. Future work will also focus on automatic segmentation using PCA analysis.

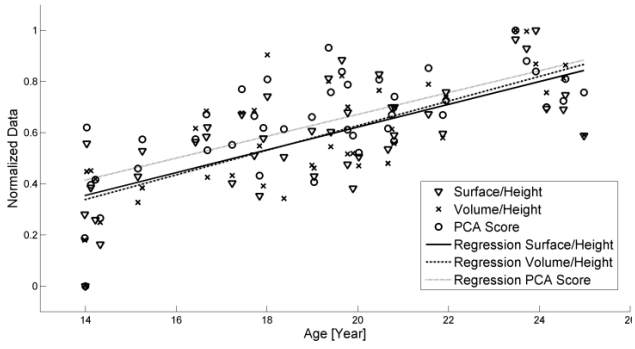

Fig. 3: Manubrium variation with age.

References:
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