MRI of the Costochondral Junction: A potential method for age estimation in the living

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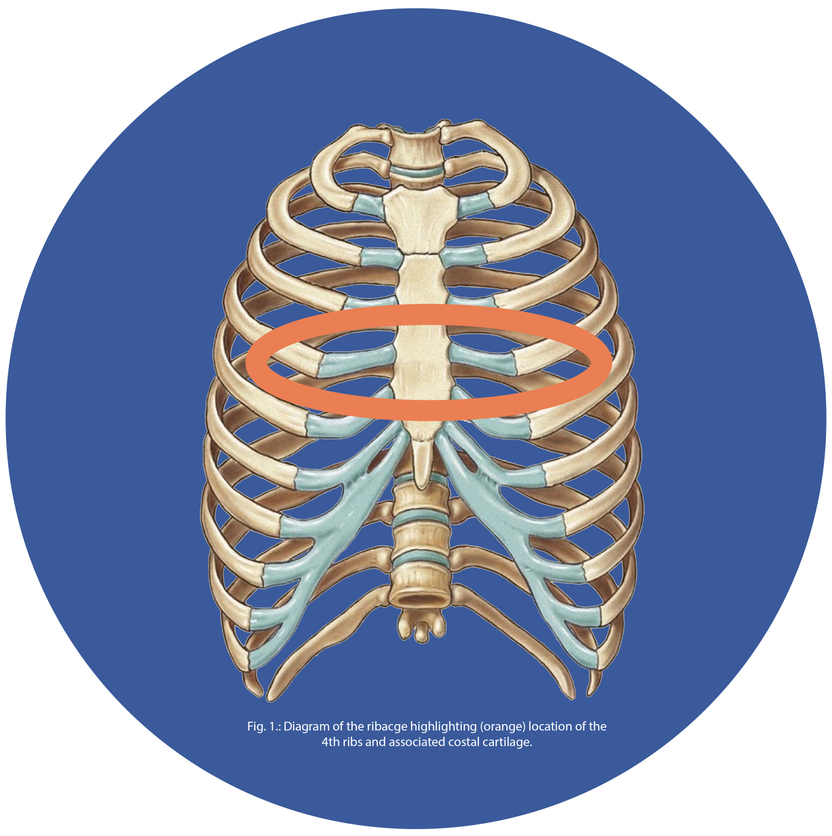

Fig. 1.: Diagram of the ribacge highlighting (orange) location of the 4th ribs and associated costal cartilage.

INTRODUCTION

Forensic identification of humans (both living and deceased) relies on understanding aspects of human anatomy and the environment. When positive ID is not available then we aretasked with creating a biological profile of the individual to aid in the identification process. Analysing age-related changes in bones thorugh physical examination or X-Ray/CT scans is widely used. However, identifying living indivudals poses radiation risks. The European Asylum Support Office advocates radiation-free methods, aligned with the European Commission's Science for Policy Report (2018). They recommend further MRI studies to enhance the knowldge in this area. Over the past several years, there has been a small body of research which is slowly growing on the implementation of MRI to forensically age individuals (Pennock et al., 2018, Schumacher et al., 2018, Schmidt et al., 2017).

An area of the body that is used to estimate age is the sternal end of the 4th rib (Iscan et al 1984, 1985) with production of physical casts in 1993 (Iscan et al., 1993) (Fig. 1). As technology and medical imaging improved and becomes more accessible, there have been a handful of articles published on age related changes to the ribs using CT scans (Trodi et al., 2016; Merritt, 2018). Because there are age related differences present on the anteriorly facing roughened surface of the rib, there should be evidence of the same changes on the corresponding lateral surface of the joint in the costal cartilage.

Therefore, this study hypothesises that age-related changes in the costal cartilage could provide a viable method for age estimation in adults over 18 years.

METHOD

A proof of concept study was conducted with 9 adult volunteers aged 18 years and older. Each participant underwent a chest MRI using a Siemens 3T Lumina Scanner. The scanning window was specifically focused on the costal cartilage from the 1st to the 5th ribs (Fig. 2). Rib cartilage segmentation was performed using 3D Slicer software. Ethical approval was granted by Bournemouth University and volunteers were fully debriefed before sign-up. Exclusion criteria for volunteers were any known trauma/incident to the chest/cartilage and any medical implants that could affect both volunteer and scanner. All scans were anonymised apart from basic biological data such as age at scan and sex.

Each rib cartilage was segmented using 3D Slicer (Fig. 3).The joint surface of each left rib cartilage (n=9, age range = 21- 51years) was analysed by placing a closed loop and resampling to obtain ten points providing x, y, and z coordinates (Fig 4). Coordinates were then saved as a .fcsv and imported into 3D Slicer's plugin "Slicer Morph". A GPA was then applied onto the data to correct and adjust for size (not shape). From this a PCA was computed, and the first two principal components were used to visualise the dataset (Fig 5.).

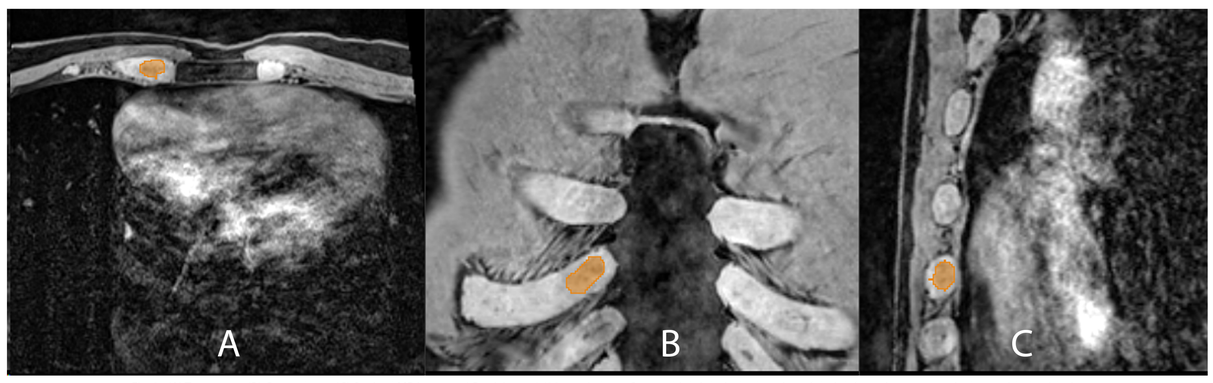

Fig. 2.: (A) Transverse, (B) Coronal, and (C) Sagittal MR images of Participant 1 (39years) chest. Orange highlight is the location of their left cartilage that articulates with the 4th rib.

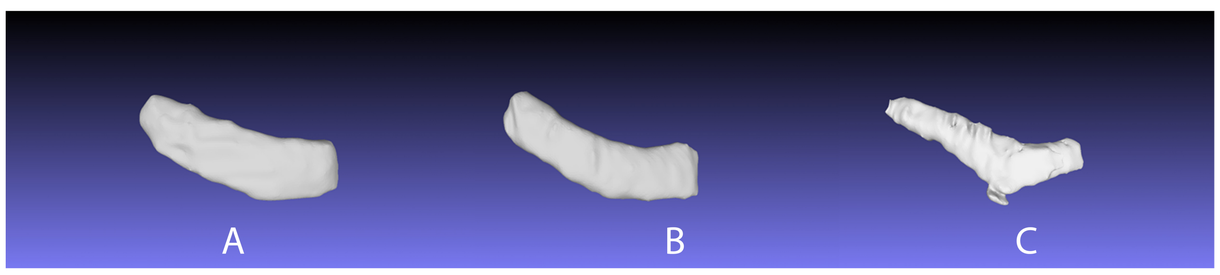

Fig. 3: 3D reconstructed cartilage of the left 4th rib. A = 21years, B = 39 years, C = 51years.

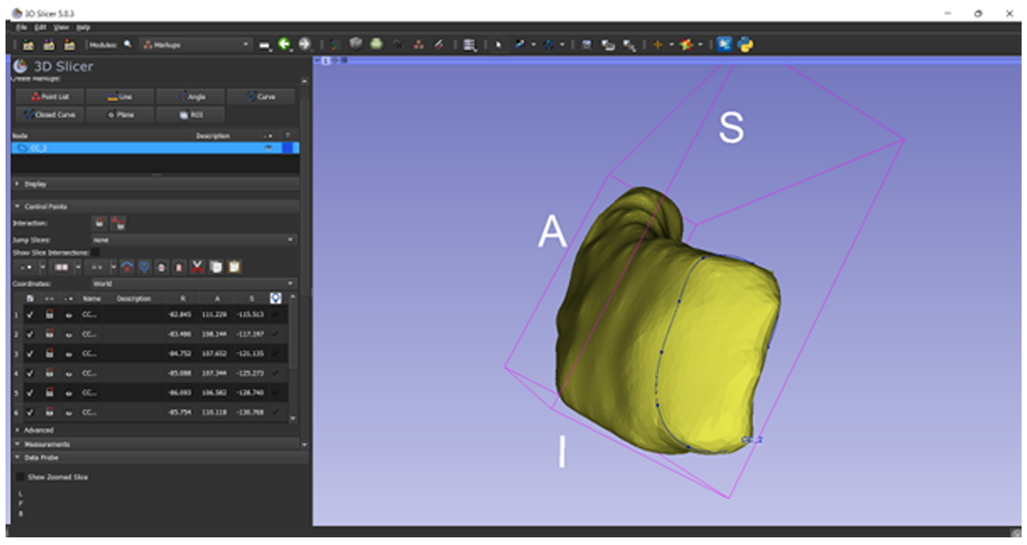

Fig. 4.: Screenshot of 3D slicer with recontructed cartilage showcasing semilandmark placement for the GMM analysis.

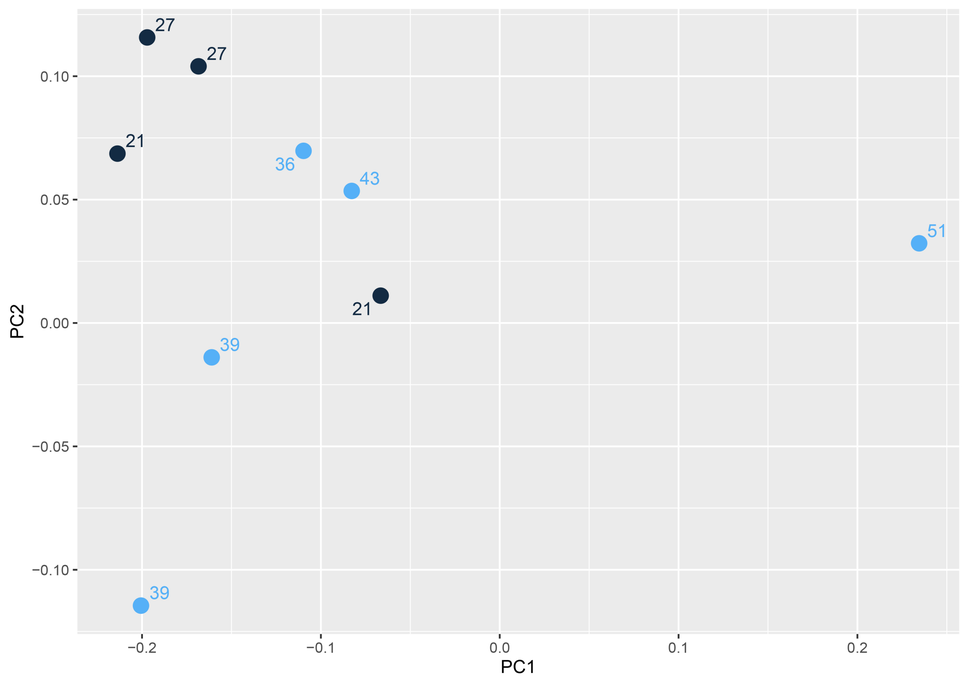

Fig. 5.: Scatter-plot showcasing the results from the Principal Components Analysis. Dark blue = <30years, Light blue = >30 years

RESULTS & DISCUSSION

The geometric morphometric analysis revealed age-related differences between the participants. Specifically, distinctions were observed between individuals under 30 years and those over 30 years of age. An outlier was identified in the under-30 group, attributed to an irregular shape at the costochondral junction. Additionally, a significant deviation was noted in the 51-year-old participant, likely due to microfractures within the cartilage structure. A primary limitation of this study is its small sample size (n=9), therefore any correlations found could be explained by individual human variationand limited information on lifestyle that could have potentially impacted their morphology.

Future research will require a larger sample size and a robust questionnaire to capture potential variables influencing morphology. Ongoing efforts include applying Iscan et al.'s methods (1984, 1985) to moulded digital rib ends to assess their applicability for age estimation based solely on cartilage (Fig 6).

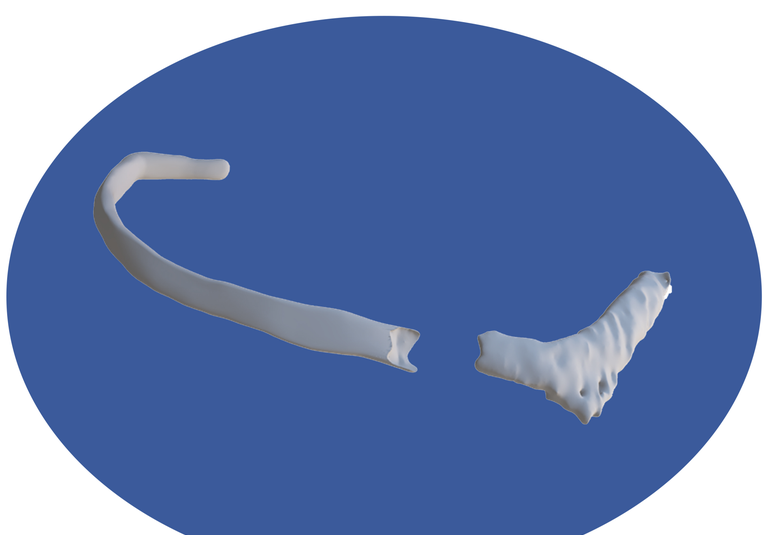

Fig. 6.: 3D reconstructed right cartilage from MRI (Participant 8, 43 years) with generic 3D 4th rib model after sternal end has been moulded to fit the cartilage.

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