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THORAX 3D MODELING FROM COSTOVERTEBRAL JOINT COMPLEX KINEMATICS: PRELIMINARY RESULTS

[1] Benoît Beyer, [1] Véronique Feipel, [1] Jérôme Coupier, [1] Olivier Snoek, [1] Pierre-Michel Dugailly, [1] Serge Van Sint Jan, [1] Marcel Rooze

[1] Laboratory of Anatomy, Biomechanics and Organogenesis (LABO), Université Libre de Bruxelles, Brussels, Belgium

email: bbeyer@ulb.ac.be, web: http://homepages.ulb.ac.be/~labo

SUMMARY

In this paper, *in vivo* computed tomography (CT) imaging data were obtained from one asymptomatic subject. The subject was asked to maintain thoracic poses for three different lung volumes (from total lung capacity (TLC) to functional residual capacity (FRC)).

Fusion methods including 3D modelling and kinematic analysis were then used to provide 3D costovertebral joint (CVJ) visualisation This procedure was performed using virtual palpation [6] in a custom-made software called lhpFusionBox [7] . Kinematics was processed using orientation vector position (OVP) method and helical axes computation.

Helical axis (HA) representation was achieved. CVJ displacements were interpolated between the discrete positions. A novel rib-specific anatomical coordinate system is proposed in order to represent rib motions. The ROM of the seven true ribs and the associated vertebrae was measured.

Such processing provided advanced representation of bone motion, continuous kinematics and helical axis representation. HA parameter in CVJ gives a new opportunity to work with. Data collection and treatment following this protocol is in progress for strict validation.

INTRODUCTION

The CVJ is an anatomical complex that is mechanically involved in both respiratory function and thoracic spine stability [1, 2]. For the last decade CVJ has been the topic of various studies aiming to increase our understanding of the thorax mechanical behaviour. Most of the previous experimental studies related to CVJ provided *in vitro* data during loading tests [3, 4] or global lung volume change analysis [5].

Functional impairments of both respiratory function and thoracic spine demonstrated kinematics involvements as well as quantitative than qualitative. The aim of this study was to develop a 3D kinematic model to represent thorax bony elements motion during the respiratory cycle, focusing on CVJ in terms of rotation around each anatomical axis, starting from the beginning, middle and end of the respiratory cycle. Results are presented using bone and joint modeling and movement representation including helical axis.

METHODS

Subject

The Radiologic department of ULB Erasme Hospital used a trial protocol approved by the local ethic committee (P2005/021) for thoracic cage imaging at three different lung volumes in asymptomatic volunteers. One data set of a 22 years old female subject was used.

Medical imaging and 3D bone model reconstruction

Computed tomography (Siemens SOMATOM, helical mode, slice thickness = 0.5 mm, inter-slice spacing = 1 mm, image data format: DICOM 3.0) was performed at three different lung volumes: - Total lung capacity (TLC); - Middle Inspiratory Capacity (MIC); - and Functional Residual Capacity (FRC).

CT data were processed using data segmentation to obtain 3D modelling of all CVJ bones (Amira 4.0) in three discrete positions (Fig. 1).

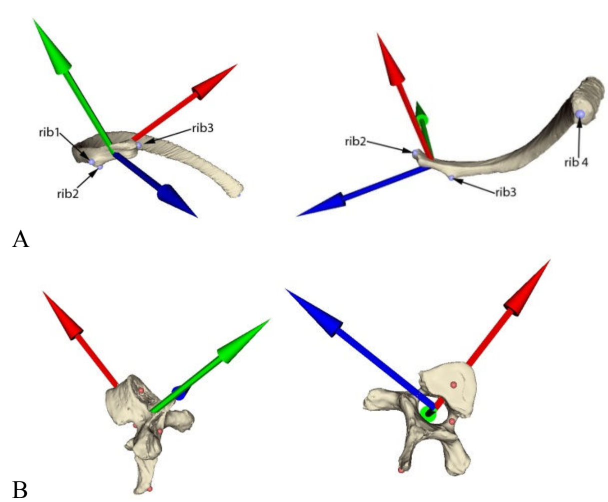

Figure: **1**: Virtual palpation to determine anatomical bony landmarks.
A: 4 rib landmarks palpation with local coordinate system
B: 6 vertebra landmarks palpation with local coordinate system

Kinematics computing and analysis

Virtual palpation procedure was then used to determine 4 (ALs) on each bone. ALs allowed to create vertebra and rib anatomical coordinate systems corresponding to the CVJ (Figs. 1 and 2) and to determine the discrete CVJ joint kinematics. The latter kinematics was then computed according the ISB recommendations ISB [5].

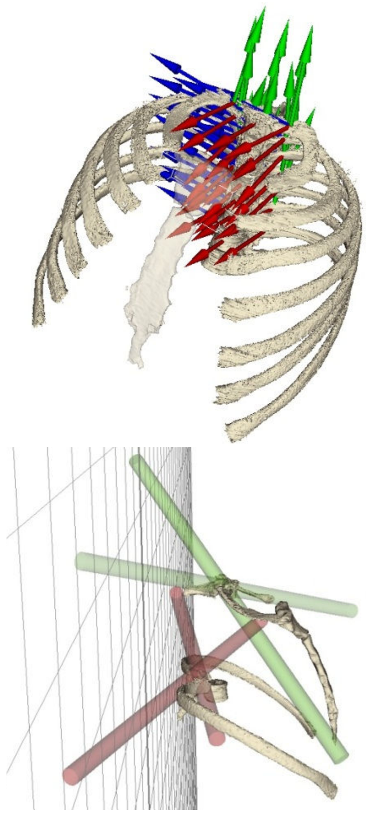

Figure: **2**: Example of local ISB oriented anatomical coordinates system (above) and MHA visualisation for first (green) and seventh (red) levels.

Interpolation was used to simulate and visualize continuous motion through each discrete position. From the above data, MHA parameters (i.e. orientation and position) were determined and integrated into the 3D model to represent the instantaneous and mean HA axis behaviour over the CVJ range of motion.

RESULTS AND DISCUSSION

Local coordinate system

From AL coordinates, novel rib and vertebrae anatomical coordinate systems are proposed for CVJ motion representation and CVJ standardisation for each level of the thorax.

Range of motion

Results are defined in terms of rotation around x, y and z axis as θx; θy and θz.

HA orientation and location

For global motion, mean and instantaneous HA were determined and visualised. Although no comparison is possible with only one subject, a first observation was that the MHA displays different orientation compared to rib neck axis (fig 3).

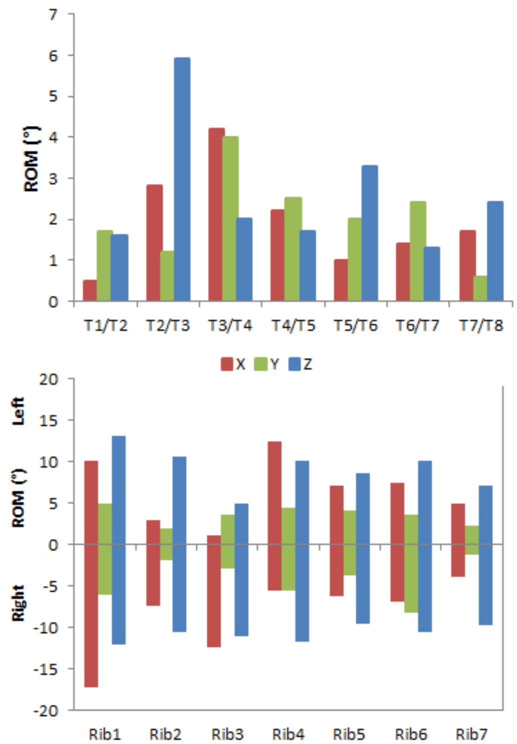

Figure **3**: ROM (°) of thoracic vertebrae (top) and left and right ribs (bottom) relative to the corresponding vertebrae.

CONCLUSIONS

An *in vivo* thoracic spine and rib cage model was obtained for the seven true ribs. This study proposes a new protocol to analyse CVJ kinematics during breathing motion allowing *in vivo* data collection and fusion into subject-specific CVJ 3D model. Such processing provided advanced representation of bone motion, continuous kinematics and helical axis representation. HA parameter in CVJ gives a new opportunity to work with. The processing of 20 asymptomatic subjects data is in progress.

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