KINEMATICS ANALYSIS OF THE COSTO-VERTEBRAL JOINT COMPLEX

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SUMMARY
The costo-vertebral joint (CVJ) complex is a structure that is mechanically involved within both respiratory function and thoracic spine stability [1]. Most of the previous experimental studies concerning CVJ provided in vitro data during loading tests [3, 4]. In this paper, in vivo CT imaging data were collected for a thoracic cage in three different lung volumes (from Total lung Capacity (TLC) to Functional residual capacity (FRC)). Fusion methods were then used to register the obtained 3D rib models built from 3D anatomical model and discrete joint kinematics data to provide 3D CVJ visualisation. Helical axis (HA) representation was also obtained. CVJ displacements were interpolated between the different discrete positions including a newly-proposed rib specific anatomical coordinate system. Kinematics was processed using orientation vector position (OVP) method and helical axes computation. Results show a specific CVJ joint model with three dimensional continuous motion simulation including HA; also simultaneous segmental movement simulation and display of HA variations was shown to be feasible.

INTRODUCTION
Functional impairments of both respiratory function and thoracic spine demonstrated kinematics involvements as well as quantitative than qualitative. For kinematics, the 3D axis of rotation orientation is reported to provide qualitative data of motion. The aim of this study was to develop a 3D kinematic model to represent the respiratory motion of a CVJ in terms of rotation around each anatomical axis, starting from an interpolation of three discrete positions corresponding to 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 for thoracic cage imaging at three different lung volumes. One set of data 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: 7th Rib with the 7th thoracic vertebra in the three different positions (TLC, MIC and FRC).

Kinematics computing and analysis
Virtual palpation procedure was then used to determine 4 bony anatomical landmarks (ALs) on each bone. ALs allowed to create vertebra and rib anatomical coordinate systems corresponding to the 7th CVJ (Figs. 2 and 3) and to determine the discrete CVJ joint kinematics [2]. The latter kinematics was then computed according the ISB recommendations ISB [5].

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RESULTS AND DISCUSSION

Local coordinate system

From AL coordinates, novel anatomical coordinate systems are proposed for CVJ motion representation and CVJ standardisation.

Range of motion

Results are defined in term of rotation around x, y and z axis as $\theta_x$, $\theta_y$ and $\theta_z$.

<table>
<thead>
<tr>
<th></th>
<th>7th Rib / Th7</th>
<th>7th Rib / Th6</th>
<th>Th6 / Th7</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_x$</td>
<td>3.8°</td>
<td>4.9°</td>
<td></td>
</tr>
<tr>
<td>$\theta_y$</td>
<td>2.2°</td>
<td>0.8°</td>
<td></td>
</tr>
<tr>
<td>$\theta_z$</td>
<td>3.8°</td>
<td>4.5°</td>
<td>0.9°</td>
</tr>
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</table>

The results in terms of ROM seem to be in accordance with existing literature [3, 4].

HA orientation and location

For the global motion, mean and instantaneous HA was determined. The mean HA orientation was not oriented along the axis of the rib neck at this 7th rib level as previously used in many experimental studies, but nearer to the frontal plane.

CONCLUSIONS

Although further work should concentrate on the collection of supplementary data and on strict validation, the presented protocol is promising. This study proposes a new protocol to analyse CVJ kinematics in 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 CMJ gives a new opportunity to work with. Data collection and treatment following this protocol could lead to a complete in vivo thoracic spine and rib cage model.

References