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Original article

Morphometric changes of the cervical intervertebral foramen: A comparative analysis of pre-manipulative positioning and physiological axial rotation

Pierre-Michel Dugailly[a,*], Benoît Beyer[a,c], Walid Salem[b], Véronique Feipel[a,c]

[a] Laboratory of Functional Anatomy, Faculty of Motor Sciences, Université Libre de Bruxelles (ULB), Brussels, Belgium
[b] Research Unit in Osteopathy, Faculty of Motor Sciences, Université Libre de Bruxelles (ULB), Brussels, Belgium
[c] Laboratory of Anatomy, Biomechanics and Organogenesis (LABO), Faculty of Medicine, Université Libre de Bruxelles (ULB), Brussels, Belgium

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ABSTRACT

Background: Cervical foraminal impingement has been described as a source of radicular pain. Clinical tests and head motions have been reported for affecting the intervertebral foramen (IVF) dimensions. Although manual approaches are proposed in the management of cervical radiculopathy, their influence on the foraminal dimensions remains unclear.
Objectives: To investigate the influence of pre-manipulative positioning versus cervical axial rotation on the foraminal dimensions of the lower cervical spine.
Methods: Thirty asymptomatic volunteers underwent CT scan imaging in neutral position and axial rotation or pre-manipulative positioning. The manipulation task was performed at C4-C5 following a multiple components procedure. 3D kinematics and IVF (height, width and area) were computed for each cervical segment.
Results: The results showed that foraminal changes are dependent on motion types and cervical levels. With reference to head rotation, IVF opening occurred on the ipsilateral side during pre-manipulative positioning while axial rotation involved the contralateral side. Regardless of the side considered, magnitudes of opening were similar between both attitudes while narrowing was lower at the target and adjacent levels during the pre-manipulative positioning. Some associations between segmental motion and IVF changes were observed for the target level and the overlying level.
Conclusions: The present study demonstrated that pre-manipulative positioning targeting C4-C5 modified IVF dimensions differently than the passive axial rotation. The findings suggest that techniques which incorporate combined movement positioning influence segmental motion and IVF dimensions differently at the target segment, compared to unconstrained rotation. Further investigations are needed to determine the clinical outcomes of such an approach.

1. Introduction

Intervertebral foramen (IVF) is an anatomical area containing neural root that is potentially vulnerable (Tanaka et al., 2000). Spatial encroachment of IVF resulting from disc herniation, bony trauma, and/or intervertebral degenerative changes (i.e. uncovertebral, zygapophyseal joints) may be the source of nerve root compression, inflammation and radiculopathy leading to pain and neural dysfunction (Carette and Fehlings, 2005; Garfin et al., 1995; Woods and Hilibrand, 2015).

Head motions are known to alter the relative intervertebral positions of the cervical spine that could involve changes in IVF dimensions (Mao et al., 2016, Muhle et al., 2001, Nuckley et al., 2002, Sato and Masui, 2013). Neck extension and axial rotation to the ipsilateral side produce a narrowing of the IVF suggesting that neural compression is more likely to occur in these motion directions (Chang et al., 2017, Kitagawa et al., 2004, Muhle et al., 2001). On the contrary, flexion and axial rotation to the contralateral side yield a foraminal opening. Several clinical tests (i.e. Spurling test, Jackson test, cervical compression or traction test) have been proposed in the diagnosis of root involvement and cervical radiculopathy by linking neck biomechanics, intervertebral foramen changes (i.e. widening or narrowing), nerve root compression and symptoms (Anekstein et al., 2012; Cleland, 2007; Shabat et al., 2012; Tong et al., 2002), and some of those have been assessed by medical imaging (Muhle et al., 1998, Takasaki et al., 2009).

* Corresponding author. Laboratory of Functional Anatomy, Faculty of Motor Sciences, Université Libre de Bruxelles (ULB), 808 route de Lennik, 1070 Bruxelles, Belgium.
E-mail address: pdugaill@ulb.ac.be (P.-M. Dugailly).

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Although specific manual interventions have been proposed for targeting foramen opening in patients (Langevin et al., 2015), the understanding of foramen dimension modifications during manual procedure remains uncertain and speculative.

The purpose of the present study is to investigate the morphometric alterations of the IVF during pre-manipulative positioning of the cervical spine compared to passive axial rotation in asymptomatic subjects. The outcomes may provide more detailed information concerning the influence of manual techniques on the cervical intervertebral foramen dimensions.

2. Methods

Thirty participants were recruited by convenience sampling from the student community and hospital staff. Inclusion criteria were the absence of neck complaints, and subjects with medical history of cervical disorders, trauma (i.e. whiplash), sign of radiculopathy and morphological abnormalities (i.e. thoracic hyperkyphosis or scoliosis) were excluded from the study. Participants underwent CT scan examination (SOMATOM Siemens 32, Germany, slice thickness 1.5 mm with low-dose protocol 350, 120 kV, 150 mAs) to obtain imaging data of their cervical spine in neutral position and full axial rotation (AR) or pre-manipulative positioning.

From the entire sample, 2 subgroups of 10 subjects were randomly assessed in only one direction AR (left or right) in order to limit x-ray exposure. The third subgroup was considered in a separate protocol to investigate pre-manipulative positioning. The latter was carried out by a practitioner with 20-years of experience using a multiple component high velocity low amplitude manipulation technique targeting at the C4-C5 level (Hartman, 1997). In summary, the technique consisted in right lateral flexion, left axial rotation and slight extension to reach the pre-manipulative positioning. This position was sustained during the second CT examination (Fig. 1). Details of the procedures are to find elsewhere (Salem and Klein, 2013; Salem et al., 2013).

Both study protocols were approved by the ethical committee of the academic hospital (Brugmann University Hospital-Brussels, agreement numbers CE 2004/28 and CE 2004/30). All volunteers gave their written informed consent.

To obtain 3D anatomical modeling, imaging data were segmented using dedicated software (Amira 3,0®, Germany). This software enabled identification of anatomical landmarks by virtual palpation to determine (1) the anatomical local coordinate system (Fig. 1), hence the position and orientation of the bones (Salem et al., 2013), and (2) the intervertebral foramen (IVF) dimensions (Fig. 2) from C2-C3 to C6-C7.

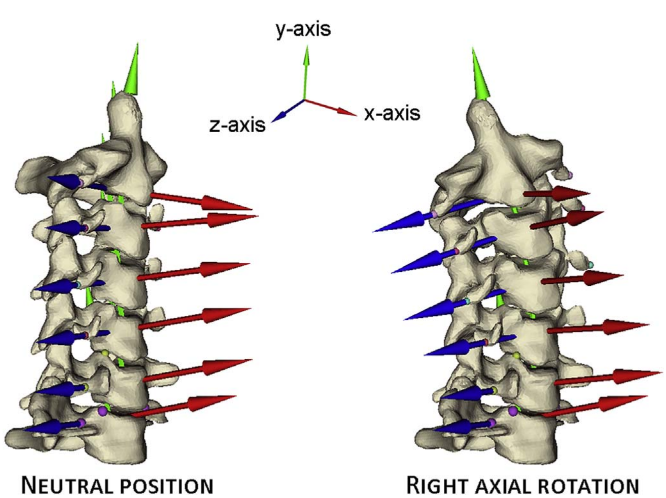

Fig. 1. 3D modeling of the lower cervical spine in neutral position and in right axial rotation (anterior oblique view). Reference frame of each cervical level is defined according to anatomical landmarks (i.e. transverse and spinous processes).

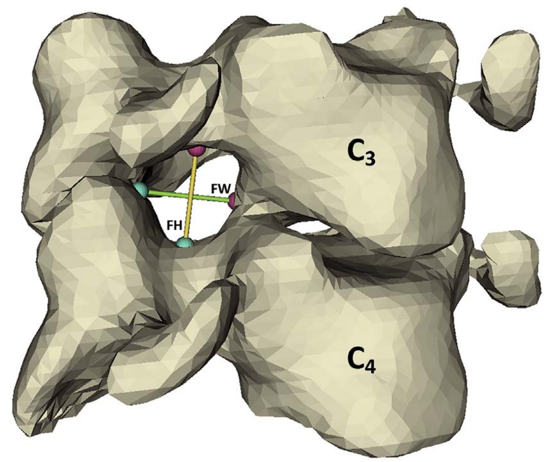

Fig. 2. Anatomical reconstruction of the left C3-C4 foramen. Height and width were estimated by computing Euclidian distances FH and FW, respectively. Each landmark (red and green spheres) centroid corresponds to the point of interest at the bony surface (see text for details). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Validity and reliability of this method have been confirmed previously for assessing cervical spine kinematics by demonstrating low angular motion errors (up to 1.5°) between assessment methods and good to excellent consistency of measurement with intraclass correlation coefficients ranging from 0.93 to 0.97 (Dugailly et al., 2013; Salem et al., 2013).

Kinematics was parameterized using the decomposition of the helical axis rotation into helical angles around the axes of the anatomical reference system (Cappozzo et al., 1995) providing output of lateral flexion (LF), axial rotation (AR) and flexion extension (FE) motion components. Intervertebral height (FH) and width (FW) were obtained from Euclidian distance between palpated landmarks on 3D models as depicted in Fig. 2. Height was estimated using the pedicle-to-pedicle distance, perpendicular to the intervertebral disc, and width was defined as the distance, parallel to the intervertebral disc, between the anterior aspect of the superior facet of the inferior vertebra and the posterolateral border of the superior vertebra (inferior plate). Assuming that the IVF has almost an elliptic shape, its area (FA) was approximated as follows:

$$FA = \pi * \frac{FH}{2} * \frac{FW}{2}$$

All 3D models were examined in neutral position and in maximal axial rotation or pre-manipulative positioning from C2-C3 to C6-C7 levels.

To assess data reliability, three operators performed 5 measurements of FH and FW on each cervical level and side of one lower cervical spine model in neutral position. Repeatability (intra-examiner variation) of measurements showed average coefficient of variation was 5.3% and 7.3% for FH and FW, respectively. Reliability (inter-examiner variation) was estimated at 5.8% for FH and 8.0% for FW. Intra-examiner intraclass correlation coefficients (ICCs) were 0.988 and 0.982, while inter-examiner ICCs were 0.978 and 0.968 for FH and FW, respectively. This indicates good repeatability and consistency of measurements.

Statistical analysis was performed using SPSS statistics software version 20.0 (SPSS Inc, Chicago, IL). Mixed model ANOVA was used to assess data differences between types of positioning (between-group factor), level and IVF side (within-group factors). When ANOVA indicated a significant difference for specific factor, Bonferroni corrections (Bonferroni post-hoc test) were used to identify significant comparisons.

Correlations between IVF changes and motion components were