

## Radiologically Guided Mobilization in Patients With Foraminal Stenosis: Impact on C5-6 Cervical Intervertebral Foramen

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### ABSTRACT

**Background:** Using CT guidance to determine the right direction of mobilization through studying the kinematics of intervertebral foramen will reduce the risk of mobilization during manual therapy interventions for cervical canal stenosis. **Purpose:** The first aim of the study was to use 3D CT to detect the proper directions of opening for C5-6 cervical intervertebral foramen. The second aim was to study the effect of mobilization on the dimensions of intervertebral foramen in case of cervical canal stenosis. **Methods:** The study included thirty male patients diagnosed with cervical degenerative disc disease with radiculopathy for at least three months up to one year and a control group of fifteen healthy subjects. Each participant was subjected to 3D CT scan from 6 separate positions in two visits to Radiology lab, 3 positions in each visit to avoid exposure overdose to X ray. The six positions were: Neutral (N) position, Lateral bending (LB), Axial rotation (AR), Flexion, lateral bending with ipsilateral rotation (FBI), Flexion, bending and contralateral rotation (FBC), and Extension with contralateral rotation (ECR). Intervertebral foramen (IVF) width and height were measured from the 3D CT in each position for both affected and opposite IVF. The direction of CT scan volume was 45 degrees with para sagittal plane and 10 to 15 degrees below the transverse plane to visualize plan of IVF. Height and width of IVF were measured for intermediate foraminal zone in each position for both control and experimental groups. **Findings:** Mixed design MANOVA revealed that IVF Height and width in the affected side increased significantly ( $P < 0.05$ ) in positions AR, LB, FBI and FBC in both experimental and control groups compared with Neutral position. However, position (FBI) showed best results among them in the affected IVF and surprisingly on the opposite side as well in all levels of IVF. **Conclusions:** Coupling motion behavior in FBI position produces foraminal opening and increases the height and width of IVF in all cervical levels in both affected and contralateral side. Although AR, LB, ECR positions increase the height and width of the IVF on the affected side, it causes significant narrowing of the IVF on the opposite side. **Implications:** Manual therapy interventions in the form of mobilization and manipulation should consider the clinical value of FBI position during physical therapy management of cervical foraminal stenosis, especially bilateral affection. Whereas AR, LB, ECR should be used only in case of unilateral foraminal stenosis.

**Keywords:** Cervical radiculopathy, Decompression, Intervertebral Foramen, Canal Stenosis

### INTRODUCTION

A cervical nerve root compression results in cervical radiculopathy, a disease characterized by discomfort and sensory impairment. Compression may be due to disc herniation, spondylosis, instability, trauma, or, in rare cases, malignancies. Patients may present with a variety of symptoms in the upper extremities, including pain, numbness, tingling, electrical-type sensations, or weakening (Mallard et al., 2022).

The precise impact of applying targeted mobilization techniques to the cervical intervertebral foramen remains uncertain, as is the effect of mobilization on the size of the intervertebral foramen. Utilizing computed tomography (CT) guidance to ascertain the appropriate direction of mobilization can improve outcomes and reduce the likelihood of complications during manual treatment for cervical canal stenosis by examining the kinematics of the intervertebral foramen (IVF).

This research aimed to quantify the dimensions of cervical IVF in cases with peripheral canal stenosis. Furthermore, the research examines the impact of both uniaxial and multi-axial postures on the diameters of the IVF in individuals diagnosed with cervical foraminal stenosis. Ultimately, this research aimed to identify the correct approach for initiating cervical IVF mobilization.

## METHODS

### Patients:

The study included 30 male patients who suffered from cervical radicular syndrome as a result of cervical disc prolapse (C5-C6). Patients were recruited from two locations: the outpatient clinic at Cairo University's Faculty of Physical Therapy and the Kaser El Aini Teaching Hospital. Fifteen normal healthy individuals served as the control group. The age, body mass index, and height of the participants did not vary significantly between the two groups. Each participant completed an informed consent form before the start of any evaluation. The study was approved by The Research Ethical Committee of the Faculty of Physical Therapy, Cairo University. The trial registry number is (P.T.REC/012/003792).

Participants were included in the study if they had paramedian cervical disc prolapse (C5-C6) persisting for a duration of three months to one year. Participants were excluded from the study if they had: severe central canal stenosis, cervical myelopathy, sequestered and migrated disc prolapse, acute discomfort (pain lasting less than three months), presence of active infection in the cervical spine, postoperative cases, suspected chemotherapy or radiotherapy and cervical instability.

### Instrumentations

#### - Philips Brilliance 64 Multi-Slice CT

Philips Brilliance series was used to assess the C5-6 IVF width and height during six tested cervical positions (**Fig. 1**). This instrument is very effective at addressing the lowest dosage size while maintaining good picture quality. The device's software includes CT viewer, MPR, MIP, 3-D SSD reconstruction, relevant slice, Master Cut, custom image filters, combined pictures, 3D small volume analysis, quantitative CTA (Q-CTA), CT time-lapse, and contrast media bolus monitoring.



**Fig. 1** Philips 64 Multi slices CT

### Procedure:

This study involved a within-subject and between-subject experimental design in which patients within the experimental group were tested at six tested positions which are: Neutral (N) position, Lateral bending (LB), Axial rotation (AR), Flexion, lateral bending with ipsilateral rotation (FBI), Flexion with bending and contralateral rotation (FBC), and Extension with contralateral rotation (ECR). Then, they were compared with normal

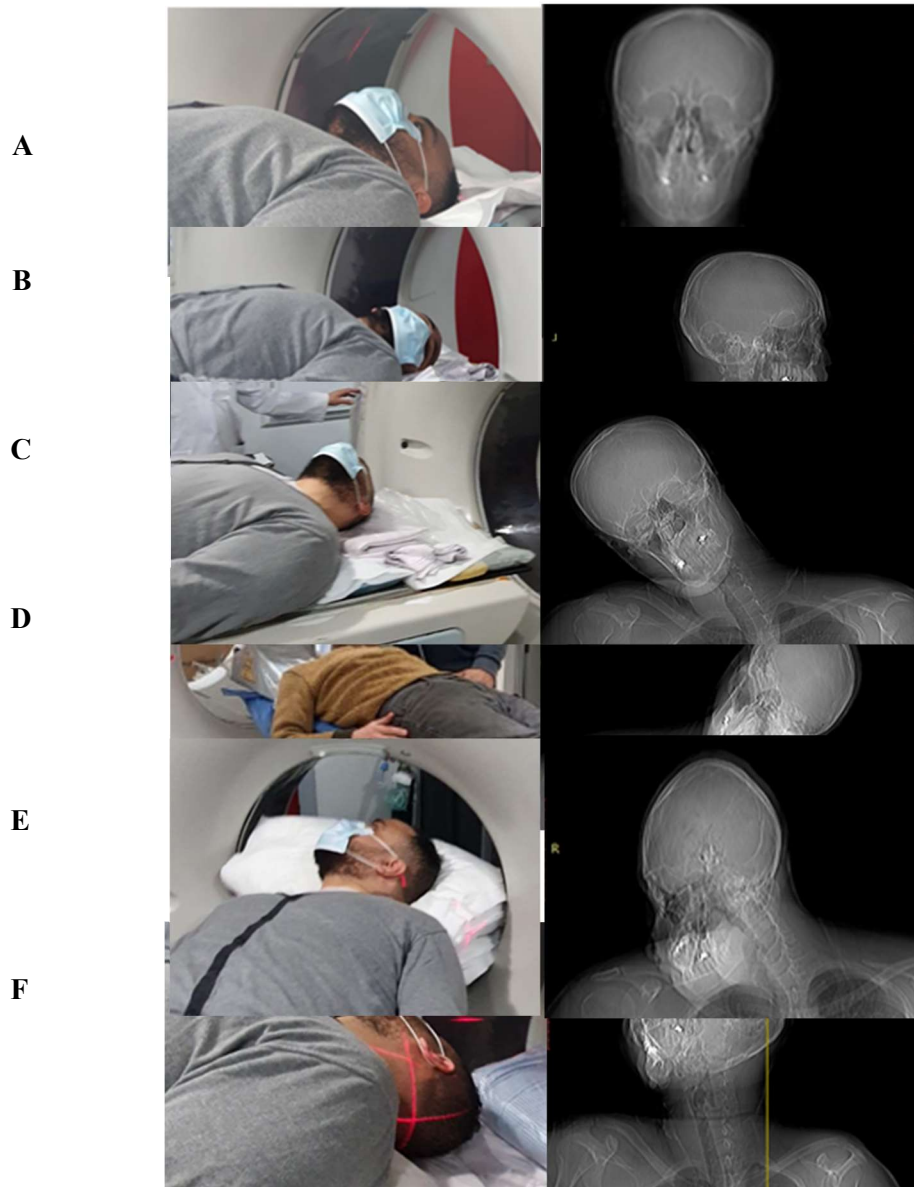
individuals within the control group. The practical part of this study lasted nine months, from March 20, 2023 to November 20, 2023.

Initially, each patient underwent neurological assessment by taking the patient's history, which included personal data, medical history, and present history. Additionally, Sensory assessment (dermatome) and motor assessment (myotomes and deep tendon reflex) were done for each patient. Then, during two trips to the Radiology lab, all patients were scanned using a 3D CT scan from the six different positions (**Fig. 2**). To minimize overexposure to X-rays, three postures were explored with each visit.

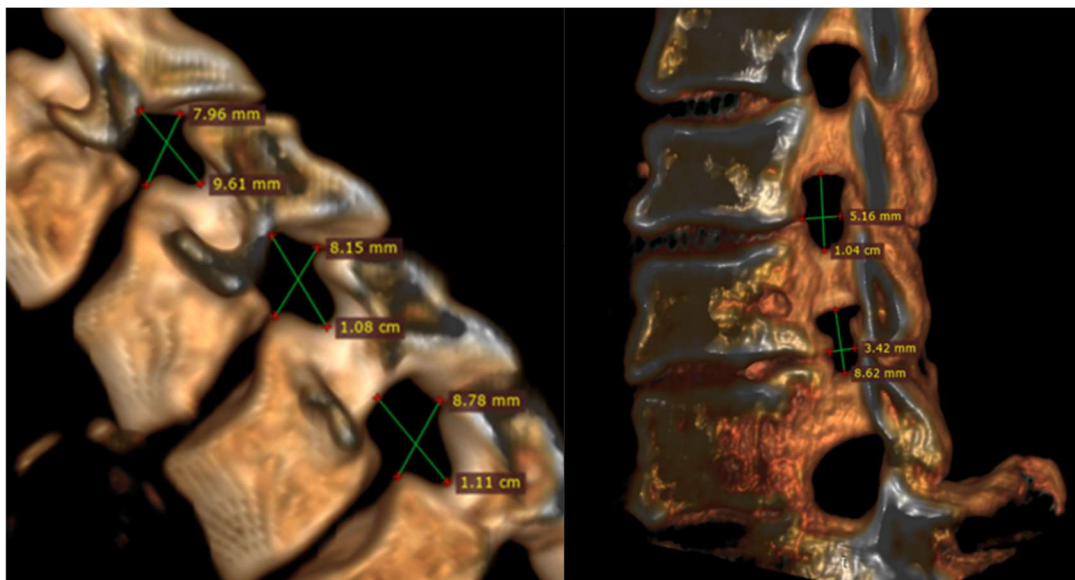
The intervertebral foramen (IVF) width & height were measured from the 3D CT in each position for both affected & opposite IVFs in the intermediate foraminal zone, from both sides of its medial and lateral surface in each position. The direction of the CT scan volume was 45 degrees with a para sagittal plan and 10 to 15 degrees below the transverse plane to visualize the plan of IVFs. Height was measured as the distance between the upper and lower pedicle. The width was measured as the distance between the upper border of the facet joint and the upper border of the uncinat process (**Fig. 3**).

### Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) version 25 for Windows was the tool used to conduct all statistical analyses. To ensure normality, which is a prerequisite for parametric analysis, the data were initially evaluated using the Kolmogorov-Smirnov and Shapiro-Wilks normality tests. In conjunction with examining extreme scores, this was also accomplished by determining whether substantial skewness and kurtosis were present. Parametric analysis was implemented once it was determined that the data did not deviate from the assumptions of normality. Two-way mixed design MANOVA was used to distinguish between the experimental and control groups for the six scanned positions for the C5–6 IVF height and width. There were two independent factors in this research. The first factor was the tested group (the experimental group and the control group) (between-subject factor). The second factor was the tested position (Neutral (N) position, Lateral bending (LB), Axial rotation (AR), Flexion, lateral bending with ipsilateral rotation (FBI), Flexion with bending and contralateral rotation (FBC), and Extension with contralateral rotation (ECR) were the six levels of the position (within-subject factor). The IVF height and width were the two dependent variables. An alpha level significance was set at 0.05.



**Fig. 2** A, Neutral (N), B Axial Rotation (AR), C Lateral bending (LB), D Flexion lateral bending and ipsilateral rotation (FBI), E Flexion lateral bending and contralateral rotation position (FBC), F Hyperextension with rotation (ER) during CT scan.



**Results**

The sample size was determined using the G\*POWER statistical program (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) based on measurements of IVF dimensions (width & height) data from pilot research with 5 participants before to the test procedures. Twenty volunteers in each group were to be appropriate. The computations have used the following values:  $\alpha=0.05$ ,  $\beta=0.2$ , effect size = 0.98, and allocation ratio  $N2/N1 = 1$ .

**Data Analysis**

Regarding the C5-6 IVF height, the two-way mixed design MANOVA revealed that there were significant within-subject effects ( $F = 53.43$ ,  $p = 0.001$ ) and non-significant between-subject effects ( $F = 3.95$ ,  $p = 0.054$ ). The subsequent multiple pairwise comparison tests revealed a significant increase in the **foramen height** in all positions compared to the neutral position in both **groups**, with a non-significant increase in the ECR position compared to the neutral position in the control group only. The highest dimensions were obtained at the FBI position in both groups.

Moreover, the foramen height values reduced significantly in the position of FBI and FBC in the experimental group compared to the control group. However, the difference between the two tested groups was not statistically significant in all other tested positions ( $p>0.05$ ) (Table 1 and Fig 4). Mixed design MANOVA revealed that IVF height in the affected side increased significantly ( $P < 0.05$ ) in positions AR, LB, FBI and FBC in both experimental and control groups compared with neutral position.

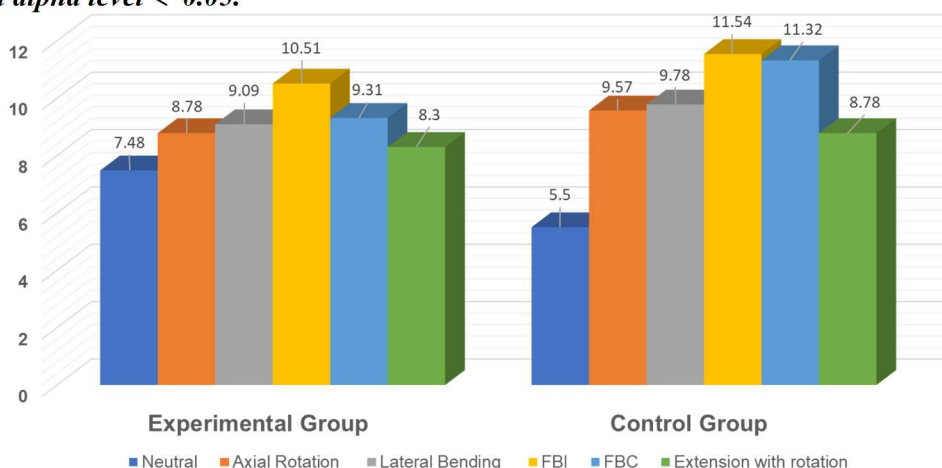
**Table 1: Descriptive statistics, Multivariate Analysis of Variance (MANOVA) and multiple pairwise comparison tests of the C<sub>5</sub>-C<sub>6</sub> foramen height of the two tested groups at the six tested positions.**

C <sub>5</sub> -C <sub>6</sub> Height(H)											
Experimental (Maximum Height of the foramen on the affected side) Mean ±SD						Control (Maximum Height of the foramen on the contralateral side) Mean ±SD					
N Positio n 1	AR Position 2	LB Positi on 3	FBI Positi on 4	FBC Positi on 5	ECR Positi on 6	N Positi on 1	AR Positi on 2	LB Positio n 3	FBI Positio n 4	FBC Positi on 5	ECR Positio n 6

7.48 ±2.48	8.78 ± 2.21	9.09± 2.65	10.51± 1.97	9.31± 2.60	8.30± 2.30	5.5 ± 1.03	9.57 1.12±	9.78± 1.13	11.54± 0.91	11.32± 0.93	8.78± 1.20
<b>Test of within subject effects (Position)</b>						F=53.43			P=0.000*		
<b>Test of Between subject effects (group)</b>						F= 3.95			P=0.054		
<b>Interaction</b>						F=3.11			P=0.034*		

Multiple Pairwise Comparison tests		
	Experimental	Control
<b>Position 1 Vs 2</b>	P= 0.000*	P= 0.009*
<b>1 Vs 3</b>	P= 0.000*	P= 0.000*
<b>1Vs 4</b>	P= 0.000*	P= 0.000*
<b>1 Vs 5</b>	P= 0.001*	P= 0.000*
<b>1 Vs 6</b>	P= 0.002*	P= 1.00
<b>2 Vs 3</b>	P =1.000	P= 1.00
<b>2 Vs 4</b>	P= 0.000*	P= 0.000*
<b>2 Vs 5</b>	P= 1.000	P= 0.000*
<b>2 Vs 6</b>	P= 0.83	P=0.043*
<b>3 Vs 4</b>	P= 0.004*	P= 0.000*
<b>3 Vs 5</b>	P= 1.00	P= .005*
<b>3 Vs 6</b>	P= 0.024*	P= .002*
<b>4 Vs 5</b>	P= .000*	P= 1.00
<b>4 Vs 6</b>	P= .000*	P=.000*
<b>5 Vs 6</b>	P= 0.117	P=0.000*
Multiple pairwise comparison tests		
<b>Experimental Vs Control</b>	<b>Position 1</b>	P=0.06
	<b>Position 2</b>	P=0.16
	<b>Position 3</b>	P=0.29
	<b>Position 4</b>	P=0.04*
	<b>Position 5</b>	P=0.002*
	<b>Position 6</b>	P=0.40

\*Significant at alpha level < 0.05.



**Fig. 4 Intervertebral foramen height in the experimental and control groups in the six spinal positions**

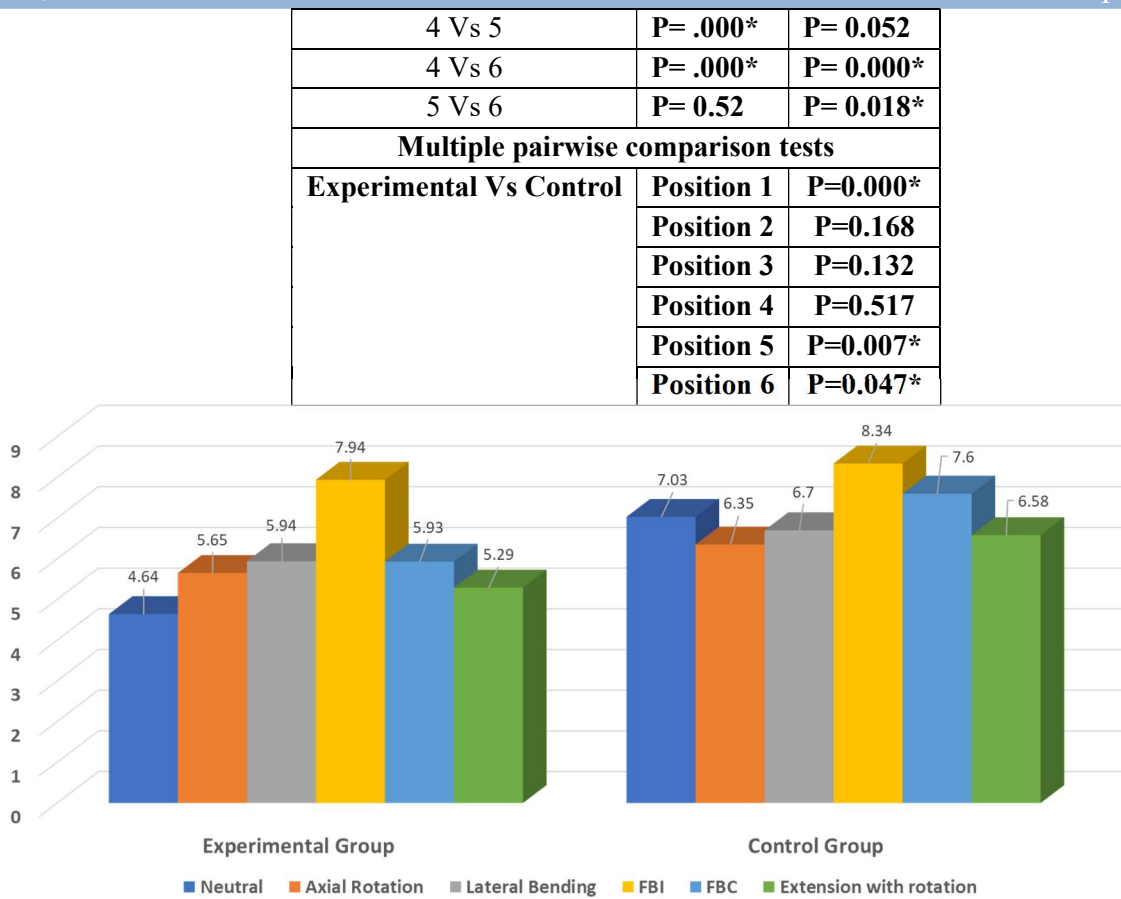
Concerning the width, the two-way mixed design MANOVA revealed that there were significant within-subject effects ( $F = 35.01, p = 0.001$ ) and significant between-subject effects ( $F = 5.771, p = 0.021$ ). The subsequent multiple pairwise comparison tests revealed a significant increase in the  $C_{5-6}$  foramen width in position LB, FBI, and FBC compared to the neutral position in the experimental group, with a non-significant increase in the other positions compared with the neutral position in the experimental group. In the control group, there was a significant increase in the foramen width in the FBI position compared to the neutral position. At the same time, there was no significant increase of width in the FBC position compared to the neutral position. Conversely, there was a non-significant reduction of width in positions AR, LB, and ECR compared to the neutral position in the control group. The highest values of the width were obtained at the FBI position in both groups.

Moreover, the foramen width measurements reduced significantly in the neutral position (N) and position FBC and ECR in the experimental group compared to the Control group. However, the difference between the two tested groups was not statistically significant in all other tested positions ( $p > 0.05$ ) (Table 2 and Fig 5). Mixed design MANOVA revealed that IVF width in the affected side increased significantly ( $P < 0.05$ ) in positions AR, LB, FBI and FBC in both experimental and control groups compared with neutral position.

**Table 2 Descriptive statistics, Multivariate Analysis of Variance (MANOVA) and multiple pairwise comparison tests of the C5-C6 width of the two tested groups at the six tested positions.**

C5-C6 Width(W)											
Experimental (Maximum Width of the foramen on the affected side) Mean ±SD						Control (Maximum Width of the foramen on the contralateral side) Mean ±SD					
N Position 1	AR Position 2	LB Position 3	FBI Position 4	FBC Position 5	ECR Position 6	N Position 1	AR Position 2	LB Position 3	FBI Position 4	FBC Position 5	ECR Position 6
4.64 ±1.77	5.65 ±1.48	5.94 ± 1.61	7.94 ±1.97	5.93 ± 2.1	5.29 ± 1.90	7.03 ±1.85	6.35 ±1.68	6.70 ± 1.48	8.34 ± 1.91	7.60 ± 1.50	6.58 ± 2.05
Test of within subject effects (Position)=						F= 35.01			P=0.000*		
Test of Between subject effects (Group)=						F=5.771			P=0.021*		
Interaction						F= 6.27			P=0.000*		

Multiple Pairwise Comparison tests		
Experimental	Control	
Position 1 Vs 2	P= 0.129	P= 1
1 Vs 3	P= 0.001*	P= 1
1 Vs 4	P= .000*	P=.001*
1 Vs 5	P= .003*	P= 1
1 Vs 6	P= .29	P= 1
2 Vs 3	P= 1.00	P= 1
2 Vs 4	P= .000*	P=.000*
2 Vs 5	P= 1.000	P= 0.023*
2 Vs 6	P= 1.000	P= 1
3 Vs 4	P= .000*	P= 0.000*
3 Vs 5	P= 1	P= .009*
3 Vs 6	P= .36	P= 1



**Fig. 5 Intervertebral foramen width in the experimental and control groups in the six spinal positions**

**Discussion**

The present study was performed to detect the proper directions of opening mobilization for cervical intervertebral foramen using 3D CT in case of C5-6 IVD protrusion. Forty-five subjects were recruited: thirty patients with cervical radiculopathy and fifteen normal subjects as a control group. Individuals underwent 3D CT scan from 6 separate positions in two visits to the laboratories, three positions in each visit to avoid overdose of exposure to X-ray. The present study revealed a significant increase in the foramen height in all tested positions compared to the neutral position in both experimental and control groups. These findings support the theory that IVFs are dynamic boundaries for the nerve root and its surrounding structures, such as venous, arterial, and lymphatic vessels. The results indicated that head and neck position modifications directly affect IVFs and the structures inside them.

The statistical analysis revealed that there was a non-significant increase in IVF height regarding (ER) position compared to the neutral position in the control group only. The combined effect of the ECR position supports this finding as ECR position has two components: extension and contralateral rotation. The effect of the ER was inconsistent with the effect of extension or rotation alone, as reported by Muhle et al. (2001), that contralateral axial rotation of 20- and 40-degree results in foraminal widening of up to 9% and 20%, respectively. On the other hand, the current study was delimited to the effect of each position on C5-6 IVF rather than the other levels.

In the present study, the highest dimensions were obtained at position (FBI) in both groups. While previous research has focused on uniplanar positions, this experiment provides a new insight into the relationship between the IVFs and the clinically relevant therapeutic multiplanar positions. FBI position is a multiplanar position of three

components: flexion, lateral bending, and ipsilateral rotation; the combined effect of the (FBI) position is the summation of the positive effect of each separate position.

An interpretation of the previous findings was reported in a recent study conducted by **Aly M. et al. (2023)**, where they concluded that during multiplanar therapeutic positions of manual therapy as in AR, FBI, FBC, and ECR positions, the behavior of vertebrae differed according to their level. At C1 the atlas follows the head position either in rotation or tilting. From C2 to C5, the vertebrae have different instantaneous axes of rotation than the lower C6-C7 and T1. During bending, coupling motion of vertebrae from C2 to C5 include rotation in the same direction of bending. Vertebrae C6, C7, and T1 have rotation in the opposite direction of lateral bending except in the FBI position.

These findings were inconsistent with **Fryette's principles**; who stated that if the primary axis has been changed to axial rotation instead of lateral bending, facet joints and disc spaces were in loose packed positions in the convex side of lateral bending. Multiplanar therapeutic positions have different arthrokinematics that are inconsistent with Fryette's principles of coupling movements in the cervical spine.

The findings of the current study are consistent with the study of **Sato & Masui (2013)**, where they concluded that cervical flexion increases the foraminal height, width, and foraminal cross-sectional area. **Schafer et al. (1990)** found that the greatest rotation below the axis (C2) occurs in the C5-C6 section, with slightly less rotation above and much less rotation below. The maximum degree of lateral bending occurs in the C3-C6 segments and diminishes towards the tail end. The current study findings are controversial from **Muhle et al. (2001)** who stated that ipsilateral axial rotation of 20 and 40 degrees leads to a reduction in the size of the foraminal opening by up to 15% and 23% respectively however, this study indicated that adding flexion to ipsilateral rotation increased the width and height of IVFs.

In the same context, the current study revealed a significant increase in the C<sub>5-6</sub> foramen width in positions (LB), (FBI), and (FBC) compared to the neutral position in the experimental group, with a non-significant increase in the other positions compared with the neutral position in the experimental group. However, position (FBI) showed the best results among them in the affected IVFs and on the opposite side as well in C<sub>5-6</sub> IVFs. These results should be considered while treating bilateral foraminal stenosis, as coupling motion behavior in the (FBI) position produces foraminal opening and increases the height and width of IVFs in all cervical levels in both affected and contralateral sides. Although (AR), (LB), (ER) positions increase the height and width of the IVFs on the affected side, it causes significant narrowing of the IVFs on the opposite side.

In the control group, the foramen width in position (FBI) increased significantly when compared to the neutral position. Positions (FBC) did not rise significantly as compared to the neutral position. Conversely, there were no significant reductions in position (AR) and (ECR) compared to the neutral position in the control group. The highest values of the width were obtained at position FBI in both groups. The data analysis revealed that foramen width measurements reduced significantly in the (N) position and position (FBC) and (ECR) in the experimental group compared to the control group. However, the difference between the two tested groups was not statistically significant in all other tested positions ( $p > 0.05$ ).

The study demonstrates a correlation between the foramen height values and multiplanar positions as the IVF height was reduced significantly in positions (FBI) and (FBC) in the experimental group compared to the control group. However, these positions increased the height and width of the IVFs significantly in comparison with neutral positions within and between subjects in the experimental group. Similar to **Lu et al.'s (2000)** results, a 2-mm constriction of the intervertebral disc space resulted in a 30% to 40% decrease in foraminal area compared to normal foraminal area values. A 1-mm narrowing of the intervertebral disc gap reduced the foraminal area by 20% to 30%. After a 3-mm constriction of the intervertebral disc gap, there was a decrease in the foraminal area, ranging from 35% to 45%. The reduction in the space between the intervertebral discs would narrow the intervertebral foramen to a degree that would result in the entrapment or compression of the spinal nerve root. On the other hand, prolonged axial distraction may cause the separation of the intervertebral disc space and trigger the manifestation of disc tissue regeneration at both biological and biomechanical levels. (**Cole et al 2016**).

The results of **Farrell G. et al. (2023)**, showed that mobilizations administered to distinct target locations within the cervical spine can differentially modulate the stress response, may also account for the improvement in pain and NDI. The effects of upper cervical mobilization versus lower cervical mobilization on both components of the stress response simultaneously were compared in a randomized crossover trial.

The present study used the concept that dynamic head movements can be used for differential diagnosis and identifying affected IVFs for treatment goals. **Hutchins J. et al. (2023)** used a dynamic MRI compression system to simulate a Spurling test on healthy individuals, and the results demonstrated substantial alterations of the cervical foramina compared to relaxed images. The Spurling test is a provocative test that utilizes cervical spine compression and is often used as a complement to the cervical MRI in an attempt to pinpoint the source of the pain and find the narrow foramina (**Jones et al 2018**). Unlike the provocation effect of the Spurling test, the current study used opening and decompressive positions to study its direct effect on IVF dimensions.

In the same context, the present study used head position modifications to simulate the common clinically relevant therapeutic positions used in mobilization and manipulation techniques to study its effect on foraminal stenosis and the accompanying symptoms. A study conducted by **Hutchins et al. (2023)** examined images collected in flexion, extension, and rotation to demonstrate variations in the foraminal area across different locations on the oblique image plane. **Takasaki et al. (2009)** performed magnetic resonance imaging (MRI) images in several fixed positions of the head, including during a simulated Spurling test. Additionally, this experiment was conducted on a cohort of adults who were in good health. A decrease in the foraminal region on the same side as the performed Spurling test was seen on the diagonal sagittal imaging plane.

Further studies are required to explore the impact of cervical spine mobilization on different levels and curve anomalies in this specific patient group. This study should also include the evaluation of neurological alterations in the upper limbs, in addition to assessing pain and impairment. The positive findings derived from this study, particularly regarding the foraminal breadth and height, as well as the FCR HR and NDI, substantiate the need for further investigation in this field.

Future research should focus on investigating individual therapies rather than exploring multimodal methods. Although the existing evidence supports a conservative strategy, it is still uncertain which interventions are the most productive. A multimodal strategy is suggested to be more successful than choosing a single intervention (**Boyle et al 2012**). While surgical intervention may be considered for managing CR, its long-term effects are similar to those of conservative therapy. Hence, it is advisable to undergo physical therapy before considering surgery as a means of managing CR. (**Peolsson et al 2013**)

## CONCLUSION

Coupling motion behavior in the FBI position produces foraminal opening and increases the height and width of the IVFs in both the affected and contralateral sides. Although the AR, LB, and ECR positions increase the height and width of the IVFs on the affected side, it causes significant narrowing of the IVFs on the opposite side.

## IMPLICATIONS

Based on the results of the current study, it is recommended that manual therapy interventions in the form of mobilization and manipulation should consider the clinical value of the FBI position during physical therapy management of cervical foraminal stenosis, especially in bilateral affection. Meanwhile, the AR, LB, and ECR positions should only be used in cases of unilateral foraminal stenosis.

## DECLARATIONS AND STATEMENTS

**Funding:** No funding sources are reported.

**Ethical Approval:** Research Ethical Committee of Faculty of physical therapy, Cairo university approved this study (P.T.REC/012/003792)

**Conflict of interest:** The authors declared that there is no conflicts of interest.

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