Original Article

Using 3D CT Scan to Predict the Optimal Position for Nerve Root Decompression in Discogenic Patients in Upper Lumbar Level

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Abstract

Background Intervertebral foramen is the doorway of nerve root, and it plays an important role of radiculopathy and surgical treatment of intervertebral foramen diseases. O**bjectives** the aim of this study was to determine the effect of side-lying with same side rotation and opposite side bending trunk position on patient with posterior and posterior-lateral disc prolapse at T12 –L1 level. **Subjects and methods** This study was conducted on 20 male participants. The study was conducted in radiology center specialized in the spine under the supervision of teaching staff member of the radiology department. Participants were divided into two equal groups of 10. The first group (A) were patients with discogenic lesion and the second group (B) was for normal individuals. Both groups were scanned using 3D CT scan at two positions: supine position and oblique position. The measurements taken were the intervertebral foramen (IVF) length (L), width (W) and cross sectional area (A). **Results** Mixed design MANOVA revealed that there was no significant difference between supine and oblique groups in diseased group regarding L, W and A. The IVF dimensions (L and W) did not significantly change with changing the spine position, while (A) was significantly higher in group A compare with group B whether in supine position or oblique position. **Conclusion** Changing the spine position from supine to oblique rotation position had no significant effect on length and width dimensions of intervertebral foramen. Oblique position had a significant influence on increasing the IVF cross sectional area in patients with discogenic lesion.

Keywords: Decompressing Nerve root, lumber Discogenic, 3D CT scan, Spine Position

INTRODUCTION

Low back pain (LBP) is one of the major clinical and socioeconomic global health burdens. The prevalence of LBP is reported to be 31%, and lifetime prevalence is reported to be 60% to 80%. LBP is a multifactorial condition that includes physiological and psychological factors, as well as brain changes (**1**). The aetiology of lumbar disc herniation and its relationship to low back pain and sciatica are not fully understood but are likely to involve a complex combination of mechanical and biological processes. Only 4 to 6 Percent of people with lumbar disc herniation experiences severe symptoms (**2).**
In a number of patients, conservative treatment with physical therapy can relieve pain, and since the disc receives the least pressure during bed rest, it is recommended to rest for up to 1 week and then gradually return to normal activity. Surgery is recommended for patients with no relief of pain after at least 6 weeks of conservative treatment. In order to avoid irreversible changes in the nerve root structure caused by chronic compression, conservative treatment is ineffective and the diagnosis and surgical indications are clear (**3).**

Intervertebral foramen as the doorway of nerve root plays an important role of radiculopathy and surgical treatment of intervertebral foramen diseases. It is difficult to get the direct information of three-dimensional intervertebral foramen because it has an entry and exit bounded by the medial and lateral borders of the pedicles. The bony boundary of intervertebral foramen includes adjacent vertebral pedicles superiorly and inferiorly, postero-inferior margin of the superior vertebral body, disc, and posterosuperior vertebral notch of the inferior vertebral body anteriorly (**4**).

In physical therapy, positioning is most common method to decompress nerve roots and relieve pain in discogenic patient at different lumber foraminal levels. So the purpose of this study was to determine the effect of side-lying with same side rotation and opposite side bending trunk position on patient with posterior and posterior-lateral disc prolapse at T12-L1 level.

Method

This study was conducted on 20 male participants. They were divided into two equal groups of 10. Group (A) is the experimental group diagnosed with L4/L5 disc prolapse with radiculopathy with mean ± SD of age, body mass index and height of (25.5 ± 4 years), (21 ± 3) and (1.8 ± 3 m) respectively and group (B) control healthy group age, body mass index and height of (24 ± 4 years), (21 ± 3) and (1.8 ± 3 m) respectively. The study aims to investigate the effect of specific trunk position (side lying on the pain free side with rotation to the same side and side bending to the opposite side) on the geometry and biomechanical properties of intervertebral foramen in patients with disc prolapse. 3D-CT scan imaging was used to get a model of the spine. The dependent variables were intervertebral foramen (IVF) dimensions: (length L (mm), width W (mm), and cross sectional area A (mm^2) Written consents were taken from the participants to use their data in the scientific research**.**

Inclusion criteria Patient with lumber disc prolapse were included in this study, who were diagnosed with L4/L5 disc prolapse with radiculopathy for at least three months prior to investigation. Diagnosis was confirmed by physical, neurological examination (motor assessment, sensory assessment, reflexes), and radiological assessment (CT or MRI).

Exclusion criteria Patients were excluded from the study if they are females**,** age greater than 40 years, bilateral and multilevel disc prolapse, sequestrated and migrated disc prolapse, acute onset of pain (pain less than three months), presence of active infection in lumbar spine, any spinal deformities e.g., moderate, or severe scoliosis deformity (Cobb angle ≥ 25°), postoperative cases, cauda equine lesion and diabetic patients. Each participant was imaged in two positions: the first one was pre-maneuver position which was supine lying and the second position was a specific trunk position (side-lying with axial rotation to the same side and opposite side-bending).

Steps of imaging All data were acquired with a combined PET/CT in-line system (Siemens health care Gmbh, 2019 40 slice syngo Software 2020). This dedicated system integrates a PET scanner with a multi-section helical CT scanner and permits the acquisition of co-registered CT and PET image in one session**.**

First imaging picture the individual was first scanned in conventional neutral supine position. and 3D-CT scan was taken.

Second imaging picture the participant assumed a specific position which was side lying on the pain free side with opposite side trunk flexion and opposite side rotation. This was achieved by instructing the participant to lay on his pain free side over a wedge shaped pillow to achieve trunk side bending, then he rotated his trunk to opposite side of pain.

Measurement of Foraminal Length and Foraminal Width and Area

Foraminal length (height) (5) The foraminal length was defined for each temporary boundary as the line segment connecting the farthest two points in the boundary, in similar fashion to a major axis concept.

Foraminal width(5) The foraminal width was defined as the least-distance between the postero-inferior corner of the proximal vertebral body for each motion segment and the closest point on the opposing boundary line**.**

Foraminal Area The foraminal area was defined as the outline of the intervertebral foramen (IVF). The study was approved by the Ethics Committee of Faculty of Physical Therapy, Cairo university, Egypt. The registry number is P.T.REC/012/003986

Fig. (1) Measurement of IVF dimensions used in this study. FH is the foraminal height and FW is the foraminal width. **(5)**

Result

Statistical analysis was performed using the SPSS (Statistical Package for the Social Sciences) version 25 (IBM Inc., Chicago, IL, USA). Shapiro-Wilks normality test and histograms were used to test the distribution of quantitative variables to select

accordingly the type of statistical testing: parametric or nonparametric. Parametric analysis was conducted as the data were found not to violate the normality assumptions. Mixed design MANOVA was used to test between subject and within subject variations. Multiple Pairwise comparison was performed using post hoc (Tukey) test to compare each two variables. The results (as illustrated in table 1) indicated that there were no significant differences in IVF length and width in supine position in group A compared with group B. Similar results were observed in oblique position. However, there was significant decrease ($P < 0.05$) in cross section area of IVF in patient with lumber disc prolapse (group A compared with normal group B) whether the patient was in supine position or oblique position.

Table (1) Effect of group comparison on IVF dimensions (length, width and cross sectional area) in both positions (supine and oblique)

	Group A Supine position	**Group B Supine position**	**P. Value**
Length (mm)	1.72 ± 0.21	1.75 ± 0.23	0.7595
Maximum width (mm)	0.89 ± 0.15	0.8 ± 0.13	0.2223
Cross Sectional Area (mm^2)	0.37 ± 0.1	0.28 ± 0.06	0.0393*
	Oblique position		
Length (mm)	1.83 ± 0.19	1.82 ± 0.21	0.8245
Maximum width (mm)	0.9 ± 0.19	0.79 ± 0.16	0.232
Cross Sectional Area (mm^2)	0.45 ± 0.08	0.28 ± 0.09	0.0014*

Table (2) represented the comparison between supine and oblique positions whether in group (A) or (B). Statistical analysis indicated that all IVF dimensions (length, width and cross sectional area) did not significantly change ($P > 0.05$) by changing the position of the spine.

Table (2) Difference between supine and oblique positions and their effects on IVF dimensions in both groups.

Group A	**Supine position**	**Oblique position**	**P. Value**
Length	1.72 ± 0.21	1.83 ± 0.19	0.285
Maximum width	0.89 ± 0.15	0.9 ± 0.19	0.864
Cross Sectional Area	0.37 ± 0.1	0.45 ± 0.08	0.074
Group B			
Length	1.75 ± 0.23	1.82 ± 0.21	0.481
Maximum width	0.8 ± 0.13	0.79 ± 0.16	0.797
Cross Sectional Area	0.28 ± 0.06	0.28 ± 0.09	0.934

Discussion

Backache is major health problem affecting all age groups with intervertebral disc disease forming one of the major causes. The term “discogenic pain” was attributed to back pain resulting from disc related pathologies (**6**). Major surgical intervention in form of total disc excision and arthrodesis had its own pitfalls as any major surgical procedure. However with advancement of technology, minimally invasive image guided interventional techniques were introduced which included intra-discal steroids, chemonucleolysis, disc decompression, annuloplasty and various procedures using intradiscal laser device application **(7).**

In physical therapy , positioning is the most common method to decompress nerve roots and relieve pain in discogenic patient at different lumber foramina levels. Change in the geometry of the IVF has a direct impact on patient signs and symptoms. The researchers used a finite element modeling to create a virtual spine model and they were able to determine the optimal position for treating patient with posterior and posterior-lateral disc bulge based on the geometry of the IVF dimensions. They had a conclusion that the position of side-lying with axial rotation to the same side with opposite side bending is the optimal position to increase the dimension of the L4-L5 foramen and consequently a direct immediate release of the related nerve roots. They also validated the effect of this position by using neurophysiological H-reflex that confirmed their results. Interestingly enough, although they made a great effort to create this huge study, they only studied the effect of the position on one foramen (L4-L5), and still all data obtained from these studies are virtual depending on finite element modelling and are not conducted on actual spine **(8).** Moreover, none of the previous studies investigated the effect of spine position on upper lumber segment which is needed in clinical practice specially T12-L1

The current study searched for the optimal position for directly decompressing nerve root in upper lumber discogenic patient using 3d CT scan of spine. Two positions were investigated: supine and oblique positions in two equal group of participants, the first group (A) were patients with disc bulge at L4/L5 disc and the second group (B) was normal individuals taken as a

control group. Analysis of the findings revealed that there was no significant difference in IVF length and width in supine position between group A and B. Regarding the cross sectional area, there was statistically significant increase in this value in discogenic patients (group A) compared with group (B) whether in supine position or oblique position regarding upper lumbar spine intervertebral foramen T12/L1. Although the effect of oblique position was not statistically significant to increase the IVF cross sectional area, the value of this dimension increased in the discogenic patient group compared to the control group. The non-significant difference may be attributed to the small sample size (10 patients) in each group.

Several in vivo studies of **Singh et al., (9)**; and **Pai et al., (10)** have reported position-dependent morphologic changes of lumbar intervertebral foramen (LIVF). Generally, the LIVF dimensions increase in flexion and decrease in extension. The reduction in LIVF dimensions could result in increased compression on the nerve root due to facet joint motion and ligamentum flavum bulging.; therefore, a special position might change the morphology of the LIVF and lead to more pressure on and potential injury of the spinal nerve root and other positions may increase IVF as flexion and specific oblique positions like side bending with flexion or rotation exploiting the normal biomechanical rules regarding lumber spine .

In the study done by **O'Sullivan et al., (11)** showed that the decrease in cross sectional area in upright standing (8% for TS at T8-T9) compared to supine or sitting could be due to the fact that the participants in their study may have adopted a slightly slouched and comfortable upright posture since they were not instructed to hold an active and erect trunk. This study confirmed the general assumption that thoracic spine responded well to the biomechanical positions and reacted like other spine segments.

On the same context **, Ren et al., (12)** discovered that the foraminal area, height, and width decreased significantly at lumbar 1 to 5 ($L_{1–5}$) levels from neutral to extension standing position in patients with low back pain, while they did not find changes in LIVF dimensions at the lumbar 5–sacral 1 (L_5–S_1) level, although the results have been studied upper lumber biomechanical effect of change positions on L1-L2 , the study did not give us the effect of the position on T12 –L1 foramen.

On the other hand, **Senoo et al., (13)** measured the foraminal height and width in vivo using subject-based 3D CT models to characterize the complex 3D structure of the lumbar foramen. The method used in this study allowed the measurement of foraminal dimensions without considering specific obliquity of individual foramen due to lumbar lordosis and/or functional scoliosis, which may cause measurement errors. The results presented showed a decrease in the foraminal height with age even in asymptomatic male young adults and again although the results have been studied upper lumber biomechanical effect of change positions on L1-L2 , the study did not give us the effect of the position on T12 –L1 foramen, which leads to the need to knows the extent of response of this level to such biomechanical effects to see if it can be used when needed

In addition, it was found that the decrease in the foraminal area was biggest at upper lumber levels specially the $L_{2–3}$ level and smallest at the L_5–S_1 level. Similarly, **Schmid et al., (14)** reported that the foraminal area decreased significantly from upright sitting to extension supine position in asymptomatic volunteers at all lumbar foraminal levels, including the upper lumber levels . Furthermore, **Schmid et al., (14) and Zamani et al., (15)** both found a decrease in the foraminal area in extension sitting position and an increase in flexion sitting position at all levels including the upper lumber segment but unfortunately they did not report the effect on T12 – L1. However, detailed information regarding the morphological changes of the LIVF from conventional neutral supine position to hyperextension supine position has not been reported as well .

In comparison with the findings of the current study, **Bae et al., (16)** try to study the biomechanical effects that affect the upper lumber patient and comparing these effects with the lower segments. Their study was conducted on a total of 207 consecutive patients who underwent surgery for single-level lumbar disc herniation [24 with ULD and 183 with lower lumbar disc herniation (LLD)] and 40 asymptomatic volunteers were enrolled. Full-length radiographs of the spine were taken to evaluate pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), thoracic kyphosis (TK), lumbar lordosis (LL), and sagittal vertical axis (SVA). There were significant differences in PI, SS, PT, LL, and SVA between the ULD, LLD, and control groups. PI in the ULD (40.9) was significantly lower than in the LLD and control groups (48.8 and 47.6, respectively). LL was significantly lower in the ULD than in the LLD (-32.4 and -40, respectively). There were significant differences between the three groups in Roussouly types. The LLD had a significantly higher proportion (62.6 %) of type 2 lordosis (flat back), and the ULD had a higher proportion (33.3 %) of type 1 lordosis than the other groups, although this study is a little far from current study, it carries a lot of biomechanical meanings specially when we refers to the difference between the biomechanical effects on upper versus lower lumber levels.

Some limitations in the current study should be considered. First, the subjects involved in our study were mainly young volunteers; therefore, the changes might be different in older people and patients with lumbar spine diseases. Second, the subjects in the current study were scanned in a conscious state, which might not accurately reflect the intraoperative changes of LIVF dimensions. The exact changes during the operation should be further investigated in future studies. Third, the experimental group was patient with L4-L5 disc lesion not T12- L1 which raises the question of whether this will have an effect and change the result. Forth the sample size was small in this study and the effect of small sample size on the extent of such negative result is questionable

Conclusion

The IVF dimensions of the upper lumbar region (height, and width) did not significantly change with changing the position of the spine from supine to oblique position. On the other hand the cross sectional area was significantly greater in patients with discogenic lesion compared with control group in both supine and oblique positions.

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