Journal of Medical Sciences

ISSN 1682-4474

Research Paper

J. Med. Sci., 14 (5): 235-240
1st July, 2014
DOI: 10.3923/jms.2014.235.240

Correlation of Axial Vertebral Rotation with Nerve Root Involvement: The First Clinical Study in Literature

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Segmental instability is known as an underlying mechanism of degenerative vertebral and intervertebral disc changes. Based on a new finding an axially rotated lumbar vertebra may be occasionally spotted on lumbar magnetic resonance (MR) images obtained in non-weight-bearing position. This study was performed to examine the possibility of an association between this new finding and nerve root involvement in the lumbar spine. A total of 54 lumbar MR images of patients with signs of nerve root involvement in the lumbar spine were reviewed. An axially rotated lumbar vertebra was reported when at extreme parasagittal sections the posterior borders of two successive vertebral bodies were not aligned. Association of these rotations with radiculopathy and sensory/motor involvement in the corresponding regions in the lower extremity was examined. The mean pain severity was 7.59±2.10 (min-max: 3-10). There was a significant direct correlation between VAS and the linear amount of axial rotation ($r = 0.73$, $p<0.001$). There was also a significant, reverse correlation between the linear amount of axial rotation and the mean anteroposterior diameter of the neural foramen at the side of rotation ($r = -0.91$, $p<0.001$). Radiculopathy was concordant with axial rotation of the lumbar vertebrae in 88.9% of the cases. Both the linear amount of the axial vertebral rotation and anteroposterior diameter of the neural foramen were significantly associated with deficit in tactile sensation. Axial rotation of the lumbar vertebra is possibly an underlying cause of radiculopathy/back pain and sensory deficient in the lower extremities. This association is probably mediated with the involvement of neural elements in narrowed neural foramen at the side of rotation.

Key words: Axial rotation, lumbar vertebra, back pain, radiculopathy, nerve root compression

JMS (ISSN 1682-4474) is an International, peer-reviewed scientific journal that publishes original article in experimental & clinical medicine and related disciplines such as molecular biology, biochemistry, genetics, biophysics, bio-and medical technology. JMS is issued eight times per year on paper and in electronic format.

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INTRODUCTION

The spinal column comprises the pivotal part of the human skeleton. Its role is to support the body, provide the ability of flexion, extension and rotation and protecting some of the most vital organs such as the cord and associated nerves located inside it (Yang *et al*., 2011).

As a result, any problem in the spinal column may lead to defective performance of the spine and spinal nerves and emergence of sensory deficit, motor shortcomings and development of pain and weakness (Avcu *et al*., 2012).

The quality and quantity of these problems are directly associated with the location of the problem in the spine and its extent (Seiz *et al*., 2009; Uchida *et al*., 2009).

In many cases with low back pain, the spine itself is intact while the connected nerves, may become impinged or traumatized (Banczerowski *et al*., 2009; Bolton *et al*., 2009; Munting, 2010). Disc herniation, spondylolisthesis, degenerative changes, etc., are common causes of nerve compression and low back pain (Shakeri *et al*., 2011a, b; Feiz *et al*., 2012; Daghighi *et al*., 2013; Fouladi, 2013).

The normal range of motion in a normal spine is 85° of flexion, 30° of extension and 28° of lateral bending (Fransen *et al*., 2008). Therefore, any displacement out of these ranges may cause problems such as pain, paresthesia and muscle weakness in that region (Wang *et al*., 2007). Axial rotation is a known cause of this derangement, however, the known axial rotation in the literature is a dynamic condition which is only evident when external loading is applied in the direction of laxity (Muhle *et al*., 2001).

Magnetic Resonance (MR) imaging is an accurate modality for documenting such rotations under axial loads (Yoo *et al*., 1992). In the present study, however, for the first time in the literature, an imaging finding in MR sequences has been introduced that reflects the presence of fixed axial rotations in some cases with low back pain. In such cases the posterior borders of the two adjacent lumbar vertebrae are not inline in sagittal views, representing the presence of some sort of axial rotation which may impinge the corresponding intervertebral nerve(s) and produce pain in the lower lumbar spine. This study was aimed to investigate a possible association of routinely unjustified low back pain/radiculopathy with such axial rotations evident in sagittal MR images.

MATERIALS AND METHODS

After being approved by the Ethics Committee of Tabriz University of Medical Sciences, 54 patients with unjustified low back pain/radiculopathy and evident axial rotation(s) in the lumbar vertebrae on MR images were enrolled in this prospective study in Tabriz Imam Reza Teaching Center from April 2013 to May 2014. Informed written consents were obtained from the participants.

Axial rotation was present when the posterior borders of two adjacent lumbar/lumbosacral vertebrae were not aligned in extreme parasagittal views by MR imaging unilaterally or bilaterally in opposite directions (Fig. 1). The amount of axial rotation was measured linearly by the difference between the locations of the posterior borders of the two vertebrae.

Concomitant disc herniation, spinal canal stenosis, spondylolisthesis, spinal tumors and infectious spondylitis were the exclusion criteria.

All the patients were examined by a skilled neurologist who was unaware of the findings in MR images. The origin of radiculopathy in the spinal column was estimated by clinical examination in each patient.

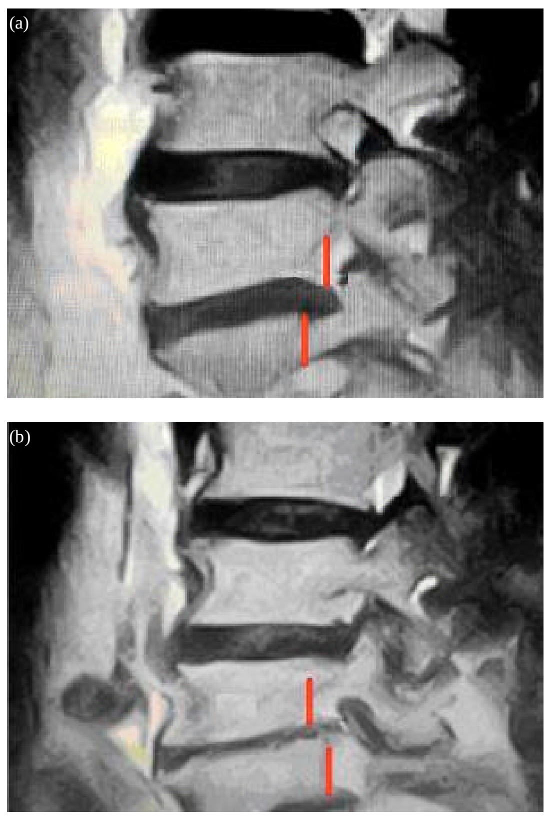

Fig. 1(a-b): Axial rotations of fifth lumbar vertebra (a) Clockwise and (b) Counterclockwise

Visual Analogue Scale (VAS) was used for reporting severity of low back pain/radiculopathy. For this purpose, a ruler scaled from 0-10 was used and the patient was asked to assign a number between 0 and 10 which best described her/his pain. Zero meant no pain and 10 indicated the most sever pain (Fouladi *et al*., 2013).

Contrast-enhanced MR images of the lumbar spine were obtained at sagittal and axial T1 and T2 weighted sections using a 1.5 Tesla scanner (MAGNETOM Avanto 1.5 Tesla MRI system; Siemens, Erlangen, Germany).

MR images were reviewed by two adroit radiologists individually and the location and amount of axial rotation(s) were reported. In terms of any inconsistency, a third radiologist was consulted. There was an excellent agreement between the two radiologist (kappa = 0.94). The radiologists were unaware of the reports provided by the neurologist.

Finally, the concordance rate between the location of axial rotation and clinically speculated origin of radiculopathy was calculated.

Statistics analysis: Data was analyzed using SPSS software version 16. One-way ANOVA, Pearson's correlation and kappa tests were employed. A $p>0.05$ was considered statistically significant.

RESULTS

A total of 54 patients with low back pain/radiculopathy and evidence of axial lumbar vertebral rotation on MR images including 26 males (48.1%) and 28 females (51.9%) with a mean age of 52.67±11.32 years (min-max: 31-71) were studied. The axial rotations were present at L3-4 in 2 cases (3.7%), at L4-5 in 30 cases (55.6%) and at L5-S1 in 22 cases (40.7%). The mean linear amount of axial rotation was 8.13±2.27 mm (min-max: 4-12). The mean anteroposterior diameter of the neural foramen on the side of rotations was 1.65±1.23 mm (min-max: 1-14) and the mean pain score according to VAS was 7.59±2.10 (min-max: 3-10) (Table 1).

In 48 patients (88.9%) the muscle strength of the lower extremities were normal and in 3 patients (5.6%) it was slightly decreased (4/5). In 3 patients muscle strength could have not been measured due to uncooperative patient.

In 37 patients (68.5%) no sensory deficit was documented in the lower extremities. In 9 cases (16.7%) sensation of the pain-temperature was compromised and in 8 patients (14.8%) abnormality in tactile sensation was present.

In 48 patients the location of radiculopathy determined by neurological examinations corresponded well with the location of the axial lumbar vertebral rotations. Only in 6 patients (11.1%) they were different. The mean amounts of axial rotation in patients without sensory abnormality, with abnormality in pain-temperature sensation and in patients with tactile sensory problems are compared in Table 1.

According to one-way ANOVA, a significant difference was present ($p = 0.01$), which was between normal subjects and the later group (Tukey *post hoc* test $p = 0.01$).

Correlations between the quantitative variables are summarized in Table 2. Accordingly, age was not correlated with these variables. There was a direct, significant correlation between the amount of axial rotation and VAS ($r = 0.73$, $p<0.001$). There was also a significant, reverse correlation between the amount of axial rotation and anteroposterior diameter of the neural foramen at the side of rotation ($r = -0.35$, $p<0.001$). Similar significant, reverse correlation was present between VAS and anteroposterior diameter of the neural foramen at the side of rotation ($r = -0.77$, $p<0.001$).

Table 1: Mean axial rotation and anteroposterior diameter of the neural foramen on the side of rotation stratified by the status of sensory involvement in the lower extremities

Variables	Normal sensory	Abnormal sensation of pain-temperature	Abnormal tactile sensation	p-value
Axial rotation (mm)	7.54±2.27	8.78±1.39	10.13±1.89	0.01*
Anteroposterior diameter of the neural foramen on the side of rotation (mm)	2.02±1.24	1.11±0.78	0.50±0.53	0.001*

Data is shown as Mean±SD, *p<0.05 is statistically significant

Table 2: Correlation between the numerical variables

Correlation	Pearson's correlation (r)	p-value
Age vs. pain	-0.17	0.22
Age vs. axial rotation	-0.12	0.38
Age vs. anteroposterior diameter of the neural foramen on the rotation side	0.11	0.44
Axial rotation vs. pain	0.73	<0.001*
Axial rotation vs. anteroposterior diameter of the neural foramen on the rotation side	-0.91	<0.001*
Pain vs. anteroposterior diameter of the neural foramen on the rotation side	-0.77	<0.001*

*p<0.05 is statistically significant

DISCUSSION

In the present study the association between axial lumbar vertebral rotation and radiculopathy/low back pain was investigated for the first time in the literature. It has been previously shown that segmental instability is a major cause of low back pain (Haughton *et al*., 2002; Blankenbaker *et al*., 2006).

This instability is an abnormal response of a segment to exert external forces, so that the movements of lumbar compartments beyond of that be in a normal condition (Frymoyer and Selby, 1985).

In contrast to axial rotation in segmental instability, however, the condition that was examined in the present study was evident in MR images without external moments/forces.

It has been shown that segmental instability causes low back pain through various mechanisms. One of these mechanisms is induction of degenerative changes in the intervertebral disc and the body itself, which may lead to compression on the nervous elements in the spinal canal or neural foramen and finally cause pain (Haughton *et al*., 2000).

Pouriesa *et al*. (2013) have shown the anatomical disproportion between two adjacent vertebrae may cause intervertebral disc herniation in the region.

So, it could be hypothesized that in cases with axial rotation, distribution of pressure that in normal condition is inappropriate, which may finally cause pathological changes and pain.

Panjabi (2003) have shown that the cause of a connection between segmental instability and low back pain/radiculopathy is an adoptive mechanism after extreme contraction of the peripheral muscles.

In the present study it has been shown that there was a great concordance between radiculopathy and axial rotation in the lumbar vertebra (88.9%).

Friberg and Hirsch (1949) shown that vertebral instabilities are underlying cause of low back pain in one third of the patients. Blankenbaker *et al*. (2006) reported a significant association between axial rotation in each motion segment and low back pain/radiculopathy, which was elicited by discography. They also showed that the concordant pain was associated with the amount of axial rotation in the corresponding vertebrae at the same level. Similar findings were also documented in the current study.

Haughton *et al*. (2002) reported higher amounts of axial rotations in the cases with concordant low back pain in comparison with those in which there was not an association between the rotation and pain.

In line with these findings and the results of our report it was concluded that the amount of axial rotation is directly associated with low back pain at the same level.

As mentioned before, it is probable that an induced stress on adjacent connective tissue (Atlas and Delitto, 2006) and narrowed neural foramen (lateral spinal stenosis) (Haughton *et al*., 2002; Blankenbaker *et al*., 2006) justify such associations between axial rotations and pain in these patients.

In addition to an association between axial rotation and low back pain, we found other correlations with significant clinical consequences. One of these findings was a significant, direct correlation between the anteroposterior diameter of the neural foramen and the amount of axial rotation at the same level. This finding supports the notion that mechanical pressure on neurons in the neural foramen may cause pain in cases with axial rotation (Yoo *et al*., 1992). Similar conclusion was drawn by Fujiwara *et al*. (2001), who examined 39 patients with axial rotation in the lumbar spine and low back pain.

Although, it is possible to report neural foramen stenosis as a possible cause of back pain with unknown origin, using routine imaging techniques such MR and computed tomography may underestimate the extent of such narrowing. Changes in the diameter of the neural foramen and the patient movement have been implicated in this regard (Leone *et al*., 2007).

It should be born in mind that the neural foramen narrowing is not always associated with radiculopathy, unless the compressed nerve is injured or there is a direct mechanical compression on a ganglion (Friberg and Hirsch, 1949).

Changes in size of ganglions and nerve root from one level to other, as well as from one person to another (Panjabi *et al*., 1994) makes low back pain and radiculopathy a nonspecific predictor of neural foramen stenosis. This may justify existence of asymptomatic stenosis of the neural foramen in many cases.

This may also justify the interesting findings of the present study in terms of the association between sensory abnormalities and axial rotation. The position of sensory fibers in the neural foramen is a possible cause of this pattern of involvement, in which there was a significant difference between pain-temperature and tactile sensations related to the axial rotations seen in the present study.

CONCLUSION

This study showed that a novel finding indicating evident axial lumbar vertebral rotation in MR images is possibly the main cause of low back pain/radiculopathy in a considerable portion of patients with no routine underlying cause(s). Further studies are recommended in this regard due to its novelty. The effect of external factors such as age (Babaeinejad *et al*., 2011; Fattahi *et al*., 2011; Navali *et al*., 2011; Amirnia *et al*., 2012; Khodaeiani *et al*., 2012; Babaeinejad and Fouladi, 2013; Baharivand *et al*., 2013; Khodaeiani *et al*., 2013) should be investigated in this regard, as well.

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