THE EVALUATION OF UNSTABLE LUMBAR-SACRAL JUNCTION WITH FUNCTION X-RAYS FILMS

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ABSTRACT

Background: Dynamic radiographs are commonly used to demonstrate segmental instability by demonstrating a varying range of motion and sometimes paradoxical movement of its articulating elements. The disparity is observable and measurable at the opposite extremes of motion; maximum extension and flexion. The level of dissociation within a segment that is responsible for the instability may be partial or complete. Partial dissociations are of two types, anterior or posterior and are referred to as anterior or posterior resistant failure. Complete dissociation is also referred to as circumferential failure. Theoretically, measurement values should reflect and differentiate these pathological processes. This study will look at any discernible patterns that would be useful indicators of instability. These findings are correlated with MRI scans which show the level of disease.
Objectives: To determine the reliability of dynamic X-ray views in the diagnosis of lumbosacral junction instability in individuals with chronic low back pain.
Design: Case control study.
Methods: Two hundred and one patients with chronic low back pain were subjected to dynamic lumbar-sacral plain films as part of clinical evaluation. The views taken are anteroposterior and two lateral views done in maximum tolerable extension and flexion with patient standing with hips and knees extended. A total of 88 patients with lumbosacral junction degeneration were selected for the study. This degeneration consisted of reduction of disc space height, facet arthropathy, fractures through the isthmus, formation of syndesmophytes etc. Measurements to determine extension and flexion angles were done on these films using the Cobb method. The difference between the extension and flexion angle was taken as the flexion arc (range of maximum motion).

The MRI scans of all the 88 patients were then carefully analysed for tell-tale signs of instability such as disc degeneration (annular fissures), vacuum sign, traction spurs, Modic changes, facet joints osteoarthritis or oedema of the isthmus etc. Thirty seven with signs of segmental instability became the study group 1 and the remaining 51 without any signs of instability made the control group 2.
Results: A total of 88 patients with monosegmental degenerative disc disease at the lumbosacral junction were analysed. There were 57 women and 31 men. There were no statistical differences between the gender distributions (P >0.10098) within the groups. There were no statistical differences in the age distribution (P >0.82337) within the groups. In the study group the mean extension angle was 31.1˚ compared to 19.6˚ in the control group (P = 0.50367). The range of motion was minimal in the study group (ROM = 3.3˚) compared to control group (ROM = 10.2˚), P = 0.00036. Seventeen segments showed paradoxical movement under stress; mean ROM -5˚ compared to 10.2˚ in the control group (P = 00001).
Conclusions: In patients with chronic low back pain, apart from the well-known paradoxical movement dynamic films in an abnormal segment will show a large extension angle (> 30˚) with a reduced range of motion (< 5˚). MRI as a stand-alone modality does not unequivocally confirm or reject segmental instability.

Key words: Lumbosacral spine, Dynamic radiography, Instability, Range of motion

INTRODUCTION

One of the indications for surgery in patients with chronic low back pain is segmental instability. Spinal stability is defined as the ability for the vertebrae to maintain the anatomical relationship with one another under physiological loading. This loading is from various postural positions and active loading of day to day activity. The vertebral column must maintain stability to prevent premature mechanical and biologic failure of its articulating components; failure which may result into impingement on the nervous tissue (spinal cord and nerve roots), deformity and pain.

The lumbar spine supports the proximal body while transmitting compressive and shearing forces to the lower body during the performance of day to day activities. Mechanical stability of the vertebral column is maintained by the normal functioning of the discs, facet joints, ligaments, and musculature. Therefore, degenerative processes in the disc and facet joints may cause instability of the motion segment affected. In the lumbar spine degeneration is believed to start in the intervertebral disc where progressive biochemical and structural changes take place; resulting into a gradual disruption of the collagen fibres, reduction in the proteoglycan contents and desiccation (1). This leads to loss of elasticity and eventual disc fissuring and annular tears. This process leads at some point into a supero-inferior narrowing of the disc and eventual collapse of the intervertebral space. This collapse leads to bulging of the posterior longitudinal ligament with the annulus attached to it, anterior bulging of the flaval ligaments with consequential narrowing of the central spinal canal; and of the inferior recesses of the neural foramina (2).

Intervertebral disk degeneration and consequent collapse allow laxity of the posterior ligamentous structures responsible for the facet joint stability leading to craniocaudal subluxation of these joints. The subsequent stresses on the facet joints result in osteoarthritis with osteophyte formation. The osteophytes impinge and narrow the lateral recesses of the central spinal canal and of the neural foramina.

Osteoarthritis of the facet joints may occur independently without degeneration of the disc and like in any other synovial joints it's characterized by the thinning of the cartilage, sclerosis of the subchondral bone, osteophyte formation, synovial inflammation, and capsular ligament laxity (3). Intervertebral disk degeneration and osteoarthritis of the facet joints, with consequential loss of their normal structural support, allow shear movement between the adjacent vertebrae. As degeneration continues, the end result is forward slippage of a vertebra on the subjacent one in the sagittal plane (spondylolisthesis). Newman and Stone in 1963 categorized this type as degenerative lumbar spondylolisthesis (4). The type of spondylolisthesis where vertebral slippage is backwards is referred to as retrolisthesis.

Unlike at the L4-5 level which has a more sagittal orientation of facet joints making this level more amenable to slippage, the L5-S1 level has a higher preponderance of coronal orientation of the facet joints (5). The lumbosacral disc is the largest disc of the lumbar spine and the lumbosacral junction enables considerably more motion than the other lumbar segments.

Functional radiography in the sagittal plane (lateral view) can be achieved in flexion and extension (6). Because of its simplicity, low expense, and wide availability, functional flexion-extension radiography is the most widely used method in the imaging diagnosis of lumbar intervertebral instability (7-10). The flexion-extension lateral views disclose abnormal vertebral motion which is an indicator of instability. Other indicators of instability on MRI scans include black and fissured disc on T2 weighted scans, vacuum sign, traction spurs, Modic changes in end plates, facet joints osteoarthritis or oedema around the isthmus.

Instability requires to be confirmed before deciding on any surgical procedure. The type and extent of surgery will depend on the degree of instability. Therefore, understanding the kinematics of this segment is imperative. Flexion-extension lateral views allow measurement of the sagittal translation and rotation. Translation of a vertebra with respect to the underlying one is measured and reported as a percentage while vertebral rotation in the sagittal plane is defined by the angle of variation between two adjacent vertebrae as observed between the extremes of movement. These measurements can be done in standing or decubitus position. Several authors (11-14) have evaluated patients with low back pain (± spondylolisthesis) and found intervertebral motion to be higher when flexion-extension radiographs were done with the patient in the standing position compared with recumbent.

MATERIALS AND METHODS

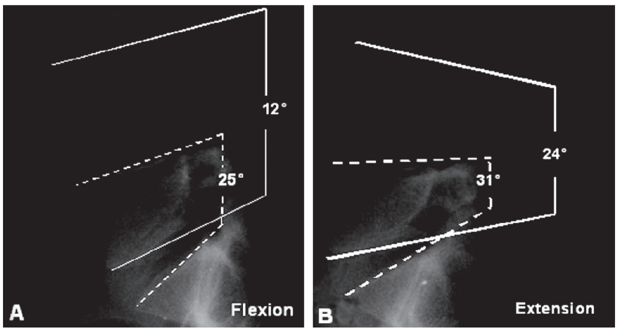
Two hundred and one individuals with chronic low back pain studied were investigated for lumbosacral junction instability between January 2013 and December 2014. Out of these radiographic film materials from 88 patients were found to have monosegmental degeneration at L5S1 level. All patients were above 21 years of age. All patients had dynamic (functional) lumbar-sacral plain films and MRI scans done. The dynamic lumbar-sacral plain films were done with the patient standing. Inclusion criteria included patients with low back pain for at least 6 months. Exclusion criteria consisted of all patients with history of previous lumbar spine surgery and patients with history of trauma. X-ray films showing signs of tumour or infection and those showing multisegmental degenerative lumbar disease were excluded. Patients with spine deformity, osteoporosis, obesity (BMI >30) and inflammatory joint disease were also excluded and so were individuals with overt spondylolisthesis.

The study group (group 1) consisted of patients with monosegmental disc degeneration at L5S1 with signs of instability while the control group (group 2) consisted of patients with a normal L5S1 segment on plain radiography and MRI. The lateral radiographs were all taken with the patients in standing position. To obtain dynamic radiographs, the patients were asked to bend forward and backward as much as it was tolerable (maximum flexion and extension). All movements were performed actively without external passive force. All the radiographs were taken in similar settings with the same digital machine by the same radiographers, using the same technique.

Measurements for spatial movements between L5 and S1 were done on these films using the Cobb's method. The Cobb angle, named after the American orthopaedic surgeon John Robert Cobb (1903–1967), measures the segmental lordosis between the affected segments. A line is drawn parallel to the superior vertebral end plate of the upper vertebra in this case L5. Another line is drawn parallel to the inferior vertebral end plate of the lower vertebra in this case S1. The two lines meet posteriorly to form an angle, the Cobb's angle (Figure 1). The segmental ROM was calculated as the difference between the segmental lordosis in extension and flexion, respectively. All measurements were performed manually and recorded on data sheet.

Figure 1

A and B, Measurement of segmental ROM with the Cobb method at levels L4 –L5 and L5–S1. Level L4 –L5 (solid line) with 12°and level L5–S1 (dashed line) with 6° of angular motion



Analysis

Three methods of statistical analysis were used to analyze the reliability measurements.

1. *Paired/unpaired t test:* The t test assesses the significance of potential variation between the two sets of measurement. The reliability is considered good/excellent if the difference is not significant ($P < 0.05$).
2. *Pearson product-moment correlation coefficient (PCC):* The Pearson PCC measures the strength of a relationship between 2 variables (e.g., the first and second measurement). Higher Pearson PCCs would indicate a better relationship of 2 sets of measurement
3. *The 95% confidence interval (CI) for measurement error:* The 95% CI provides a range that is expressed in units. Of the differences of 2 measurement sets, 95% can be expected within these limits.

Data were analyzed using the SPSS 12.0 statistical software (SPSS, Inc., Chicago, IL).

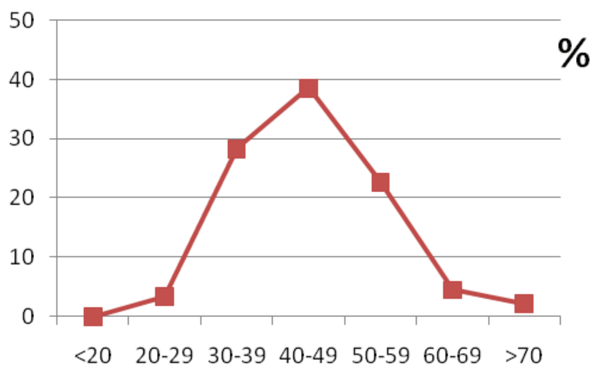
RESULTS

The majority of patients (79 = 90%) were aged between 30 and 60 years (Table 1)

Table 1

Age distribution

Age	No	(%)
<20	0	0
20-29	3	3
30-39	25	28
40-49	34	39
50-59	20	23
60-69	4	5
>70	2	2
	88	100



There were 37 patients in group 1 (unstable segment) and 51 in the control group (stable segment) Table 2.

Table 2
Frequency distribution

Diagnosis	Frequency	(%)
Group1	37	42
Group 2	51	58
Total	88	100

Table 3
Age distribution within the groups

	Mean	SD	95% CI	T-Test
Group1	44	12.2	4.1	0.82337034
Group 2	45	10.7	3.0	

There were 57 women and 31 men. There were no statistical differences between the gender distributions (P >0.10098) within the groups (Table 4).

Table 4
Gender distribution in groups

	Group 1	Group 2	Total	P value
Male	11	20	31	0.10098
Female	26	31	57	
Total	37	51	88	

The mean difference between the genders in this study was in height and body mass. The men were taller (1.7±0.2m versus 1.6±.2m, P = 0.0000002) while the female patients were heavier (BMI 29.7±1.1 versus 26.3±1.1, P = 0.00055)(Table 5).

Table 5
Differences within the gender in the cohort

	Male	Female	SD	95% CI	P value
Height	1.7	1.6	.8	.2	.0000002
BMI	26.3	29.7	5.8	1.1	.0005537
Extension	27.0	27.8	8.0	1.3	.5304521
Flexion	20.0	20.4	8.3	1.3	.8063784
ROM	6.9	7.4	6.9	1.1	.6851457

There is increased extension in the unstable group compared to the control group (31.1°±3.6 versus 19.6±2.1, P = 0.50366) (Table 6).

Table 6
Mean extension angles (degrees)

	Mean Extension	SD	CI	T-Test
Group 1	31.080	10.7	3.6	0.5036658
Group 2	19.570	7.3	2.1	

The unstable segments remain relatively extended even on flexion when compared to the normal segment (27.8°± 11.8 versus 10.6 ± 5.0, P = 0.000413). This difference is statistically significant (Table 7).

Table 7
Mean flexion angles

	Mean	Standard deviation	CI	T-Test
Group 1	27.8	11.8	3.9	0.000413
Group 2	10.6	5.0	1.4	

Pearson product-moment correlation coefficient sowed no relationship between height and extension (r = 0.2) or between BMI and extension (r = - 0.04) (Table 8).

Table 8
The Pearson correlation Index for various parameters

	Means	PC
Height	1.63	
ROM	7.3	0.3
BMI	29	
ROM	7.3	-0.03

The range of motion was minimal in the unstable segment (ROM = 3.3˚±3.3 versus 10.2 ± 1.6, P = 0.00036) Table 9. Seventeen segments showed paradoxical movement under stress; mean (ROM -5˚ versus 10.2˚, P = 00001) (Table 9).

Table 9
Mean spatial displacement

	Mean	Standard deviation (sd)		CI	T-Test
Group 1	3.3		9.8	3.3	.000357
Group 2	10.2		5.8	1.6	

Therefore, instability greatly reduces the range of motion so does weight gain. What is not clear from this study is whether increased weight (BMI) directly reduces motion or causes instability. Table 10 summarises the findings.

Table 10
Summary of findings

	Group 1	Group 2	SD	95% CI	P value
Height	1.7	1.6	1	.2	2.1263221E-04
BMI	29.7	27.7	6	1.1	0.195688197
Extension	31.1	29.7	8	1.3	0.503665767
Flexion	27.8	19.6	8	1.3	0.000413021
ROM	3.3	10.2	7	1.1	0.000357413

DISCUSSION

The majority (90%) of patients in this study are aged between 30-60 years. This is the period where most people are most productive and engaged in intense labour. The majority of these individuals were females (65%). Unfortunately we did not breakdown these individuals to their occupations. Plain X-rays are not expensive and are widely available making functional flexion-extension radiography a simpler way for diagnosis of intersegment instability. Many surgeons have used flexion-extension lateral views in decision making, particularly when fusion is contemplated. In the background of a prolapsed disc; an abnormal vertebral motion makes a simple discectomy untenable.

Basic functional radiography is done in the sagittal plane (lateral views). Two films are taken, in maximum tolerable positions of extension and flexion (15). The patient may be either in lateral decubitus or standing positions. However, this method is challenging and debatable because of the lack of a non-traumatic and routinely applicable reference standard to define intervertebral instability (16); its reproducibility is also difficult as slight variation in patient positioning or in the direction of the X-ray beam may result in a 10%–15% variation in the range of vertebral displacement (17). The appropriate way to obtain flexion-extension radiographs whether decubitus or standing and standardized methods of measurements of angular and translational displacements are still to be validated (18-20). Some authors (21-22) have found intervertebral motion to be lower when functional radiographs are obtained with the patient in the recumbent position compared with standing. Wood *et al* (23) has recommended flexion-extension radiographs be obtained in the lateral decubitus position in patients with unstable spondylolisthesis, to maximize the chances of detecting maximum abnormal translational movement in the sagittal plane. In this study all the functional films were done in the standing position. The flexion-extension lateral views allowed measurement of the spatial displacement at the lumbosacral junction by comparing the Cobb angle between the two opposing vertebral end plates at extremes of motion. Translation in the sagittal plane was not measured in this study.

As much as flexion-extension lateral views are a rough and imprecise method to detect lumbar intervertebral instability they are a useful indicator for instability. CT Imaging provides a detailed view of spinal degenerative changes and the facet joints. MR Imaging is the most accurate imaging method for degenerative abnormalities of the spine, and is often used as the diagnostic modality of choice for patients with chronic low back pain. However, identification of patients with an increased chance of instability is increased by the combination of MR images and functional radiography. This was the approach in this study where suspicious signs of instability on MRI scan led to functional radiography. The salient signs we looked for in the MRI scans to delineate a segment as unstable were Modic changes types 1–3, traction spurs at end plates, disc annular tears and facet joint arthropathy. The association of vertebral instability with changes in the bone marrow adjacent to the end plates (Modic changes), has been inconclusive (27, 28). Some authors have reported significant association between radiographic instability and traction spurs and between radiographic instability and disc annular tears (29, 30). Therefore, flexion-extension radiographs should be considered in patients with annular tears or traction spurs. Degenerative disk disease and facet joint osteoarthritis affect the stability of the motion segment. However, the exact relationship between degenerative disk disease, facet joint osteoarthritis, and vertebral instability at MR imaging has not been defined (31).

There was increased postural extension in the unstable group (mean 31°) compared to those with stable segments (20°). The angular movement in the sagittal plane is also limited in the unstable group (mean 3.3°) compared to the stable group (mean 10.2°). Therefore, instability compromises the range of motion (reducing or even reversing the spatial displacement in the sagittal plane. In this study, it is also observed that increased weight (BMI) relates positively to instability (Pearson correlation index r= -0.03), whereas height alone does not influence abnormal motion at the lumbosacral junction.

The cutoff between normal and abnormal movement is also difficult to determine. A large range of normal motion has been reported with a substantial overlap of symptomatic and asymptomatic motion patterns; sagittal rotation may be as high as 25°in healthy young volunteers (24). However, values of >10° for sagittal rotation are typically used to infer instability (25, 26). In this study the average angular displacement in the sagittal plane was 3.3° compared to 10.2° in the control. Both the study and control groups were symptomatic for low back pain.

There are individuals who complain of sharp back pain only on lateral rotation or side bending. Side bending in the lumbar spine is a composite motion involving sagittal angular movement coupled by lateral rotation. Therefore, lateral translation (laterolisthesis) of one vertebra on another during lateral bending can manifest as a pathologic process (25). Radiographic indicators of abnormal movement include a loss of vertebral body movement and paradoxical opening of the disk space on the bending side (7). Side bending radiographs should be obtained if side-bending instability is clinically suspected, especially when flexion-extension radiographs are normal, but are unlikely to be helpful on a routine basis (10). In this study we did not look for side bending abnormalities.

CONCLUSION

It can be concluded that simple flexion-extension lateral views are a rough though imprecise method of detecting lumbar intervertebral instability (whether at the lumbosacral junction or any other level.

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