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Editorial

Lumbar segmental instability: Points to ponder

A motion segment is defined as the smallest segment of the spine exhibiting biomechanical characteristics similar to that of the entire spine.¹ Each motion segment consists of two adjacent vertebral bodies and the interconnecting ligaments.² A spinal motion segment can undergo two kinds of motion – translatory and rotatory.² Segmental instability occurs when an applied force produces displacement of part of a motion segment exceeding that found in a normal spine.³ Several researchers have defined normal motion in the lumbar spine. Most of these studies were performed on cadaveric spines. After due consideration of all these studies as well as spine biomechanics, the currently accepted thresholds for diagnosing instability have been put forward by Panjabi and White⁴ as 4 mm of sagittal plane translation anteriorly or 2 mm sagittal plane translation posteriorly for translational instability and for rotational instability as $>15^\circ$ at L1-L4, $>20^\circ$ at L4-L5 and $>25^\circ$ at L5-S1. More than 9° angulation in the sagittal plane has also been widely accepted.⁵ Paris⁶ defined instability as existing only when sudden aberrant motions such as a visible slip or a catch are observed during active movements of the lumbar spine or when a change in the relative position of the adjacent vertebrae are detected with palpation performed with the patient in a standing position versus palpation performed with patient in a prone position. It was put forward by Panjabi⁷ as “**A decrease in the capacity of the spinal stabilizing system to maintain within physiological limits the spinal neutral zones so that there is no neurological deficit, no major deformity and no incapacitating pain**”. Panjabi and White demonstrated that the load displacement curve of the typical spinal motion segment in highly non-linear, with high flexibility for motion occurring around the neutral position of the spine and with increased passive resistance to motion nearer the end ranges of spinal motion.⁸ Total range of motion of the spine may therefore be divided into two zones: the neutral zone and the elastic zone. The neutral zone is the initial portion of the ROM during which spinal motion is produced against minimal internal resistance. The elastic portion of the ROM is the portion nearer to the end range of movement that is produced against substantial internal resistance. The neutral zone is in the zone of high spinal flexibility whereas movements in the elastic zone encounter increased internal resistance to movement. An

increase in the size of the neutral zone relative to the total Range of motion (ROM) therefore, increases the amount of laxity present and therefore places increasing demands on the stabilizing system of the spine.⁹ In vitro studies indicate that an increase in the neutral zone may be a better indicator of segmental instability than total ROM.⁹ Panjabi¹⁰ conceptualized the stabilizing system of the spine as consisting of three subsystems: passive, active and neural. The function of these three subsystems are inter-related and dysfunction of any one of these will place increasing demands on other subsystems to maintain stability.

1. Diagnosis

In a standing position, the subject was asked to flex the trunk forward as far as possible while the examiner observed in an effort to identify any of the following abnormalities:

1. Painful arc in flexion: symptoms felt during the movement at a particular point in the motion (or through a particular portion of the range) that are not present before or after this point.¹¹
2. Painful arc on return: symptoms occur only during return from the flexed to the erect position.¹¹
3. Gower sign (“thigh climbing”): pushing on the thighs or another surface with the hands for assistance during return from the flexed to the erect position.¹²
4. Instability catch: any sudden acceleration or deceleration of trunk movement or movement occurring outside the primary plane of motion (e.g., lateral bending or rotation during trunk flexion).¹³
5. Reversal of lumbopelvic rhythm: on attempting to return from the flexed position, the patient bends the knees and shifts the pelvis anteriorly before returning to the erect position.¹⁴ Lumbar segmental instability is diagnosed based on clinical and radiological criteria. Aberrant motion patterns during trunk flexion^{11–14}, presence of palpable or visible step off between vertebral spinous processes.⁶ Posterior shear test¹⁵ 4. Prone instability test¹⁵ 5. H & I tests¹⁵ 6. Quadrant test,¹⁵ are useful clinical tests in segmental instability.

X-rays are the most widely used method to diagnose instability.¹⁶ Vacuum phenomenon-gas in the disc space is one of the earliest reported signs of segmental instability at that level,^{17,18}. End plate sclerosis is another finding suggesting segmental instability at that level.¹⁸ Traction osteophytes—osteophytes occurring 2–3 mm away from the end plate border are recognized to be indicative of instability. Claw osteophytes which are osteophytes occurring at the vertebral end plate border are also indicative of instability but represent a later stage in the evolution of the disease.¹⁹ They may however occur together on the same disc.¹⁹ Traction osteophytes (versus all other types of osteophytes or normal vertebral bodies) have a high specificity (98.1%) and low sensitivity (12.5%) in the diagnosis of segmental instability.²⁰ Absence of disc osteophytes and end plate abnormalities has a high negative predictive value for instability.¹⁹ Disc degeneration as evidenced by decrease in disc space height is predictive of anterior and posterior translatory instability.¹⁹ Facetal osteoarthritis is also a predictor for anterior and posterior translatory instability.¹⁹ Facetal osteoarthritis precedes disc changes in 20% cases. Spondylotic listhesis, degenerative spondylolisthesis and retrolisthesis are by themselves indicative of segmental instability at that level.²⁰

Special views: 1. Flexion – extension views and lateral rotation views, 2. Traction – compression views – done with weights 3. Lateral bending views (side bending views). Currently however traction-compression views and lateral bending views have been demonstrated to be of no value in diagnosing instability.²¹ Flexion – extension views were taken using standard methodology. The patient was upright, with a dorsal support placed at the level of the sacrum. He/she was asked to flex or extend the spine actively as much as possible without flexing the hips. The X-ray beam was centered at the iliac crest. Radiographs were taken with a tube-film distance of 1.5 m.²² Lateral rotation views were taken by asking the patient to rotate the trunk laterally as much as possible while keeping the hips fixed and true lateral views of the lumbar spine were taken again centered on the iliac crest and with a tube film distance of 1.5 mts.²² Radiologically there are three types of instability translatory which may be anterior or posterior, sagittal angulatory and rotary instability in the horizontal plane. Measurement of instability was done using the method of Dupuis²³ et al which is the most commonly used one. Sagittal translatory instability is diagnosed when the translation is > 4 mm or 15% of vertebral body width. The criterion for diagnosing sagittal angular instability is when the sagittal angulation is more than 10°. ²⁴ Rotary instability is manifested by a double contour of the posterior border of the concerned vertebra. A constant double contour of the posterior borders of all the vertebrae is however a consequence of oblique projection and is not due to instability.²⁵

instability and disk degeneration.²⁰ They found a highly positive association however with annular tears.²⁰

The natural history of the progression of instability biomechanically has been proposed by Kirkaldy, Willis and Farfan¹⁸. They proposed that instability passes through 3 phases-

- (1) **Stage of dysfunction** – here there is hypermobile angulation of the functional spinal units
- (2) **Stage of instability** – Disc and facet joint degeneration set in resulting in excessive translation. The loss of disc height being the first change in this stage which sets off the cascade. As the degenerative process progresses, more and more translation occurs
- (3) **Stage of restabilization** – severe loss of disc height and osteophyte formation result in restabilization of the unit and the translation will decrease. If restabilization does not occur, then pain will increase – necessitating surgery.

Surgical management is recommended for patients with severe symptoms restricting activities of daily living not responding to a trial of conservative treatment for 2 months with radiological evidence of instability i.e., sagittal translation more than 4 mm and sagittal angulation more than 10°. ²³ The current treatment for symptomatic instability in cases of spondylolisthesis, degenerative disc disease and lumbar canal stenosis is decompression, posterolateral fusion and instrumentation.^{24,25} In general, the reports on the clinical outcomes of posterolateral fusion (with or without instrumentation) for chronic low back pain have produced varying results. Good to excellent results have been reported in ranges as low as 39%–57% of patients.^{26–28} It has been proposed that one of the reasons for this rather disappointing clinical outcome relates to the biomechanical inability of posterolateral fusion alone to impart rigid immobilization of the spinal column without additionally providing anterior column support. In vitro studies that have evaluated spinal stiffness and segmental motion after simulated fusions have suggested that the posterolateral fusion mass, because of its posterior position, is biomechanically inferior to an interbody fusion mass.^{29,30} PLIF addresses by³¹ providing larger bone base for fusion-the whole of the vertebral end plates Vs only transverse process in the case of posterolateral fusion. Providing anterior support and eliminating anterior motion thus decreasing bending moments on the posterolateral graft and thus increasing fusion rates. Addition of PLIF to posterolateral fusion with instrumented biologic distraction provides superior results in the treatment of symptomatic lumbar instability.

2. MRI

The correlation of instability and disk degeneration, based on standard radiographs, has previously been suggested.¹⁸ However, a recent investigation, based on MR imaging and using quantitative assessment of disk height and disk dehydration, found no significant correlation of lumbar segmental

3. Conclusion

Addition of PLIF to posterolateral fusion with instrumented biologic distraction provides superior results in the treatment of symptomatic lumbar instability. The improvement being due to three factors, Addition of PLIF, Improved interbody grafting technique, Use of biologic instrumented distraction.

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