Spondylololisthesis I: Update, Misnomers & Insights for Non-Specific Low Back Pain

Skeletal Awareness & Dexterity

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Isthmic Spondylolisthesis (IS)
Wiltse et al 1976 classified spondylolysis and spondylolisthesis into five categories. The most common are Isthmic Spondylolisthesis (IS) and Denegerative Spondylolisthesis (DS). This newsletter and subsequent editions examines features of IS (and later DS) particularly as it relates to an understanding of spinal function and Non-Specific Low Back Pain (NSLBP). I will review the classic definition of IS and the more recent emphasis on Sagittal Alignment for its role in the definition of IS and how it pertains to quality of life with the condition and following surgical management.

Classic Definition- Misnomers

Misnomer #1: IS is classically defined as one vertebra sliding forward on another. This is not completely true. If L5 slides forward on the sacrum, what happens to the L4-5 junction? Does L5 also slide forward on L4? And then what happens to L4 on L3? Antoniades et al (2000) correctly pointed out that the entire spine slides forward on S1 (Figure 1 & Appendix). This becomes very clear with more advanced cases of IS and especially the Grade 5 IS where L5 and spine slips off the sacral plate, i.e. Spondyloptosis (Figure 1 & Appendix). Been et al (2011) reported that while L5-S1 descended from lordosis for IS, L4-5 disc space ascended into greater lordosis (13° to 11° and 9.8° to 14.8° respectively for Grades I-II L5 IS, Figure 1).

Reviewing IS is an opportunity to re-evaluate how we view spinal conditions- local versus global parameters. What the extensive investigations of IS has lead to, is a view of the spine as an entire biomechanical entity from top to bottom. IS is not just one vertebra sliding on another but the entire spine sliding on the sacrum and an ever lengthening list of parameters characterizing this condition.

There is the fracture, the slip, lumbar lordosis (LL), lumbo-sacral kyphosis (LSK), sacral slope (SS), sacral inclination (SI), pelvic tilt (PT), pelvic incidence (PI), sacral doming, sacral kyphosis (SK) lumbar index (LI), thoracic kyphosis (TK), trunk tilt (T1, T9) and more...

Spondylolysis is the defect and spondylolisthesis is the vertebral translation or slip. Fredrickson et al 1984 (and later Beutler et al 2003) followed 500 first graders over 40 years. 4.4% of the first graders had an initial defect, 19 of the 22 (86%) defects were at L5 and 15 were bilateral (79%).

The problem or the big question is- what comes first? What is the etiology of IS? The fracture? If yes, how does the fracture occur and why? L5-S1 kyphosis? Lumbar lordosis? Pelvic incidence? Turning six years of age? Athletics? Genetics? First we review some of the lengthy list IS parameters.

Figure 1 A & B: Spondyloisthesis- Slip & Lumbar Lordosis. Adapted from Boxall et al 1979, Antoniades et al 2000.

A1 & B1 represents a normal lumbar spine sagittal alignment.

A2. B2. Grade 2 Slip. Notice L5 slides forward on S1 (Middle arrow). L4-5 lordosis increases (Right arrow). L5-S1 becomes increasingly kyphotic (Left arrow).

A3. B3. Grade 4 Slip. L5-1 slips on S1. L1-5 lordosis increased. L5-S1 lordosis decreased = kyphotic.

Isthmic Spondylolisthesis I: The Defect & The Slip

The Defect

IS is defined by a fracture of the Isthmus. The Isthmus also known as the pars interarticularis or just pars is defined as a land mass connecting two larger masses, that is the bony connection between the superior and inferior facets, and hence also then the definition of pars interarticularis becomes obvious (between articulations) (Figure 2). Fracture of the isthmus always begins anteriorly (Figure 2a) (Terai et al 2010). On a normal Xray the Isthmus is obscured from view by the transverse process and hence the use of an oblique view. Figure 3 shows the separation of the posterior and anterior vertebral elements for a bilateral spondylolisthesis.

Figure 2. Isthmic fracture of a lumbar vertebra.

Figure 3. L5 Spondylolisthesis (Redrawn from Harris 1951).

The Slip

Slip measurement has been defined by Meyerding (1956) and Taillard (1976). Meyerding divided the sacral plate into four equal quarters Figure 4. L5 slip forward on S1 is then graded according to the quarter- 0-25% = Grade 1, 26-50% = Grade II, 51-75% = Grade III, 76-100% = Grade IV and greater than 100% = Grade V otherwise known as Spondyloptosis (Figure 1 previous page).

Taillard’s method measures the amount of slip of L5 on S1 as a percentage of the L5 translation and the length of the superior endplate of the sacrum as shown in Figure 5. IS is graded by millimeters, percentage or quarter but more recently it has been classified either as low grade or high grade (Figure 5a-b). Use of high and low grade classification and subsequent 6 sub-groups allows surgeons to better determine when and how to operate (Labelle et al 2011).

Unfortunately, only slip grades of III and IV correlate with health-related quality of life (HQRL) measurements (SRS-22 & SF-12) while lumbo-sacral kyphosis (LSK) and pelvic tilt (PT) correlate with HQRL independent of the degree of slip (Berven et al 2010). That is, while slip is a significant and defining measurement for IS it is not as meaningful as Lumbo-Sacral Kyphosis and Pelvic Tilt for assessing quality of life with this condition before or after surgery.

Figure 4. Meyerding’s Method for L5 Slip

\[ \text{Slip} = a-b \text{ (mm)} \]

\[ \text{Slip\%} = \frac{a-b}{a-c} \times 100 \]

Figure 5. Taillard’s Method for L5 Slip

5a. L5 slip on S1 is less than 50% = low grade IS.

5b. L5 slip on S1 is greater than 50% = high grade IS.
Pelvic Tilt (PT), Sacral Slope (SS) & Pelvic Incidence (PI)

PT is the angle subtended by a vertical line through the center of the hip joints and the line from the center of the sacral plate to the center of the hip joints Figure 6c. Sacral slope is the angle between the horizontal and the line through the superior endplate of the sacrum (Figure 6b). Normal values are given in Table 1 & 2 Appendix.

Introduced by Legaye et al (French 1993, English in 1998), PI is the angle between the perpendicular line from the center of the sacral plate and the line from the center of the sacral plate to the center of the hip joints Figure 6a. PI is the arithmetic sum of SS and PT and is claimed to be a fundamental parameter for spinal posture (Legaye et al 1998).

Mangione et al (1997) measured PI in 30 fetuses, 30 children and 30 adults. PI increased most in the first months and years stabilizing by age 10. PI increased during childhood but it remained constant for fetuses and adults. After 10 years of age, PI is considered a fixed angle. Normal values for PI: fetus 31°, child 40°, adult 55°. PI is a measure of the relationship between the sacrum and the ilia via the sacro-iliac joints (SIJ). Up to the age of 10 there must significant mobility at the SIJ's allowing for the development of a PI angle beginning with the fetus at 31° and rising to 55° by adulthood and as high as over 80° for people with IS (Figure 7, Table 1 & 2 in Appendix). After 10, PT and SS must have a relatively fixed relationship because PI has stabilized, that is, up to age 10 the sacrum and ilia can move apart but after age 10 they mostly move together as one unit (except for a small amount of SIJ motion).

Pelvic Incidence = Sacral Slope + Pelvic Tilt

Figure 6. Pelvic Incidence

Pelvic Morphology & Upright Stance

PI, PT and SS all increase with increasing severity of IS slip (Labelle et al 2004). Mangione proposed that the process of obtaining the human upright stance influences pelvic morphology (i.e. PI). In the fetus, L5-S1 has a little lordosis while the rest of the spine is kyphotic (Cil et al 2005, Choufani et al 2009). By age 3 lumbar lordosis reaches 44° and by adulthood it measures 55°. Obtaining the upright posture is complex but involves at least two major mechanical accomplishments: Hip extension and then the sacrum tilts forward to become more horizontally oriented to allow for a normal spinal LL.

The coordination or perhaps the battle between the trunk flexors and extensors in establishing an individual’s upright stance may possibly be the primary etiological parameters causing IS. Trunk or lumbar flexor action or tone is balanced by a matching extensor action to maintain an upright balanced posture. Unwanted, unnecessary, excessive flexion tone could drive an excessive extension response possibly determining the sacral and lumbar effects of IS (eg increased PT, SS, PI, LL). Excessive flexor action may also be a primary factor in Degenerative Spondylolisthesis and even Non Specific Low Back Pain - Personal hypothesis from this author. Essentially, I wonder if our spinal ailments don’t in fact evolve from how we stand in the world.

Figure 7. Excessive Pelvic Incidence. With increasing PI, the pelvis is pulled apart- the sacrum tilts horizontally and the ilia rotate forward into excessive posterior pelvic tilt.
LumboSacral Angle (LSA) for measuring Lumbo-Sacral Kyphosis (LSK)

Dubousett 1997 modified Boxall’s Slip Angle to be the “Lumbo-Sacral Angle” or “LSA” or “DubLSA”. LSA is a measure of the angle between L5 and S1 which is normally lordotic but descends toward zero and then becomes kyphotic in L5 IS (Figure 9)(Boxall et al 1979, Vialle et al 2007). Boxall considered the Slip angle to be as significant as Slip percentage in IS, while Dubousett noted that a LSK below 90° was a major factor in the progression of IS (i.e. when L5-S1 becomes kyphotic).

Figure 9. Measuring L5-S1 Lordosis for three orientations: lordotic, zero and kyphotic) using LSJA & Dub LSA.

Lumbo-Sacral Kyphosis (LSK)

Glavas et al (2009) evaluated six different methods for measuring LSA- two of these methods are illustrated in Figure 9. Figure 9 illustrates 3 possible arrangements for the L5-S1 shape- L5-S1 can be either lordotic (Normal)(9a1-a3), zero (9b1-b3) or kyphotic (9c1-c3). The Lumbo-Sacral Joint Angle (LSJA) will measure negative for lordotic angles and positive for kyphotic angles. The Lumbo-Sacral Angle (LSA) however, is always positive.

Tanguay et al (2012) found positive correlations between Slip angle, Dubousett’s LSA and LSJA and the Quality of Life for patients with IS. That is, LSK not only correlates well with IS severity of slip (Vialle et al 2007) but also with patient suffering (Tanguay et al 2012).

Vialle et al (2007) compared LSA measurements and IS slip grade for 244 IS patients and 300 controls (Table 2). Vialle stressed the significance of LSK in IS as a primary determinant for this condition.

Take Home Message:
1. Both local, adjacent and global parameters define the condition and patient suffering in IS.
2. The Lumbar Spine has regional variations and is not always a single uniform entity.
3. A vertebral Slip and the Lumbo-Sacral Kyphosis are both definitions for Isthmic Spondylolisthesis.
4. Lumbar Kyphosis and Pelvic Tilt may well be the primary etiologic factors for IS, DS and even NLBP.
Boxall et al 1979
Management of severe spondylolisthesis in children and adolescents. Observe preservation of L1-L5 lordosis versus L5-S1 kyphosis. Note JS’s progression of Slip from 97% to 135% in 10 years. Also obvious- a vertical sacrum and S1 endplate rounding.

Labelle et al 2004
Spondylolisthesis, Pelvic Incidence, and Spinopelvic balance: a correlation study

Labelle et al 2004: Table 2. Radiographic Variables in the Normal and Spondylolisthesis Population

<table>
<thead>
<tr>
<th>Variables</th>
<th>Normals</th>
<th>Spondylolisthesis</th>
<th>Grade 1</th>
<th>Grade 2</th>
<th>Grade 3</th>
<th>Grade 4</th>
<th>Grade 5</th>
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<tr>
<td>PI</td>
<td>Mean</td>
<td>51.8</td>
<td>71.6</td>
<td>57.7</td>
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<td>78.8</td>
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<tr>
<td>SS</td>
<td>Mean</td>
<td>39.7</td>
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<tr>
<td>PT</td>
<td>Mean</td>
<td>12.1</td>
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<td>13.8</td>
<td>16.2</td>
<td>27.6</td>
<td>33.9</td>
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<tr>
<td>LL</td>
<td>Mean</td>
<td>42.7</td>
<td>66.0</td>
<td>51.1</td>
<td>61.1</td>
<td>71.6</td>
<td>83.1</td>
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<tr>
<td>TK</td>
<td>Mean</td>
<td>47.5</td>
<td>38.9</td>
<td>42.2</td>
<td>41.3</td>
<td>36.1</td>
<td>38.2</td>
</tr>
</tbody>
</table>

Figure 3. Examples of changes in spinal and pelvic parameters from normal to Grade V spondylolisthesis.
Dear Doctor,

I am writing a book about the kinematics of low back pain. I wanted to share with you some of my literature research at this time. Part of this research involves sagittal vertical alignment of the spine (SVA) (i.e. simply posture). SVA is very mixed for low back pain and fraught with issues, however over the last decade SVA has been extensively investigated for spondylolisthesis and scoliosis. It turns out that SVA not only predicts the successful outcome for surgical management of these conditions but it also defines these conditions and determines patient quality of life or suffering.

Newsletters are brief but I wanted to offer a little from the world of Isthmic Spondylolisthesis to inspire a global as well as local view of spinal conditions and a reconsideration of lumbar lordosis as a single uniform entity.
Please contact for any questions or articles.

Other newsletters can be found on my web page: www.efeld.com/news:


2. The Thorax- the forgotten link in human motion. “The Snake, the Turtle and the Human Thorax”. The snake is a rib cage with a head and a tail, while the turtle’s shell is also a rib cage. We humans begin life with a flexible mobile thorax somewhat like the snake thorax and progress through life toward the turtle shell thorax. Yes, the thorax has functional mobility other than breathing and protection.


5. Vertebroplasty- the Rise and Fall of a Convenient Truth... or perhaps a Half Truth! – Video (Short 6 min or Long =28 min).

6. Core Stabilization: Rejected. Rejected by science. The Transversus Abdominis does not act bilaterally and tonically as a stabilizer as claimed, instead it acts like all other muscles to produce movement.

7. Isthmic Spondylolisthesis 1 (IS 1).
- A review of basic concepts: Newsletter.
- IS Introduction: A Spinal Story: Video (8 min).
- Measuring Lumbo-Sacral Kyphosis: Video (6 min).
- Pelvic parameters: Video (coming soon).

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Antoniades et al 2000
45 Spondylolisthesis silhouettes:
Note that the integrity of the lumbar spine from L1-L5 is maintained in L5 IS. Look closely at dotted lines on 3,7,8,9,20,26,37. Increased lumbar lordosis- Cause or Consequence? Also observe the variable and mostly kyphotic shape of the sacrum.

Vialle et al 2007 Lumbo-Sacral Angle (LSA).
LSA = angle between the line through the superior endplate of L5 and the line through the posterior border of S1.
Lumbo-Sacral Kyphosis = major deformity
- Cause or Consequence?

Vialle et al 2007: Table 1.
Pelvic and Lumbar angles for IS.

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Low (GII)</th>
<th>High (GIV)</th>
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<tr>
<td>PT</td>
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<td>23</td>
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<tr>
<td>LL</td>
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<tr>
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<td>98</td>
<td>74</td>
</tr>
<tr>
<td>LSJA*</td>
<td>-13</td>
<td>-11</td>
<td>+31</td>
</tr>
</tbody>
</table>

See text for abbreviations. * Additions from Been and Tanguay.