Spine Sagittal Balance

see Spine Sagittal Imbalance

Latest News

- Risk of proximal junctional kyphosis after revision of growing rod constructs
- Surgical Management of Lower Back Pain: Is Optimizing Spinopelvic Alignment Beneficial for Patient Outcomes?
- Bracing Outcomes in Adolescent Idiopathic Scoliosis: The Role of Generalised Joint Hypermobility
- Three-dimensional gait analysis reveals differences in spinal balance and muscle activity during prolonged walking in patients with dropped head syndrome based on global spinal alignment
- Is Anchored Stand-Alone ALIF Effective and Safe for the Treatment of Low-Grade L5-S1 Isthmic Spondylolisthesis? A Comparative Study With Posterior Lumbar Interbody Fusion
- Three-dimensional surgical correction analysis in adolescent idiopathic scoliosis treated with posterior fusion
- Longitudinal analysis of radiological parameters after monosegmental lumbar instrumentation and posterior lumbar interbody fusion (PLIF) compared with transforaminal lumbar interbody fusion (TLIF)
- Digital study and correlation analysis of sagittal balance parameters in adolescents with idiopathic scoliosis: A comparative study with healthy adolescents

---

Spine sagittal balance refers to the alignment of the spine when viewed from the side (sagittal plane). Proper sagittal balance is crucial for efficient movement and posture, minimizing strain on muscles, ligaments, and the vertebral column.

Key concepts

Plumb Line: A vertical line drawn from the center of the C7 vertebral body (the seventh cervical vertebra) down to the sacrum. Ideally, this line should pass through the posterior superior corner of the S1 vertebra. This is used as a reference to assess whether the spine is in a balanced position.

Pelvic Incidence (PI): The angle between a line perpendicular to the sacral plate at its midpoint and a line connecting this point to the axis of the femoral heads. This parameter is fixed and unique to each individual, influencing other pelvic and spinal parameters.

Pelvic Tilt (PT): The angle between the vertical and the line through the midpoint of the sacral plate to the axis of the femoral heads. It reflects the orientation of the pelvis and is a compensatory mechanism to maintain sagittal balance.

Sacral Slope (SS): The angle between the horizontal and the sacral plate. SS = PI - PT. It directly influences lumbar lordosis.

Lumbar Lordosis (LL): The inward curve of the lumbar spine. Proper lumbar lordosis helps maintain overall sagittal balance and is often proportional to pelvic incidence.

Thoracic Kyphosis (TK): The outward curve of the thoracic spine. Normal thoracic kyphosis is essential for accommodating the organs in the thoracic cavity and maintaining balance.

Sagittal Vertical Axis (SVA): The horizontal distance between the C7 plumb line and the posterior superior corner of the S1 vertebra. An SVA within 5 cm is typically considered balanced. An anterior deviation (positive SVA) indicates forward-leaning posture, while a posterior deviation (negative SVA) indicates backward-leaning posture.

Global Balance

Normal

Cervical Lordosis

normal 20-40° Thoracic Kyphosis

Normal 20-50°. This is predominantly impacted by lumbar and pelvic anatomy. Thoracic kyphosis can generally range 30 degrees more than lumbar lordosis Thoracolumbar Junction

Normally a transition from thoracic kyphosis to lumbar lordosis, the T12/L1 junction should be neutral, with less than 10 degrees or regional kyphosis. Lumbar Lordosis

Average 60° A wide range of acceptable values depending upon the pelvic anatomy As much as 75% of lumbar lordosis occurs between L4 and S1 with 40-50% occurring at L5/S1 Pelvic Tilt

Normal <20 degrees Pelvic Incidence

Normal 55 +/- 10 degrees Pelvic Incidence/Lumbar Lordosis Mismatch

Normal <10 degrees Sagittal Vertical Axis

Normal <5mm C7 Plumb Line and Sagittal Vertical Axis (SVA)

The C7 plumb line is a radiographic reference to determine the sagittal vertical axis, the most traditional measurement of sagittal balance of the spine. A vertical line is drawn from the center of the C7 vertebral body in a caudal direction. The line should connect with, or be within 5mm of, the superior-posterior endplate of S1. This is considered within the tolerable range for health-related quality of life outcomes. However, as patients age, they lean forward and tolerate slightly more positive sagittal alignment. Any surgical intervention must consider patient selection.

It remains vitally important to release the harmonious anatomy of sagittal plane consideration. The cervical spine can compensate with a hyperlordotic presentation to maintain a more neutral posture. The patient can further compensate with increased pelvic tilt and knee flexion. However, this is a physically taxing and non-anatomically normal, fatiguing position.

Pelvic Incidence

Pelvic incidence is a radiographic measurement comparing the biomechanic relationship between the

lumbar spine and the pelvis in patients with differing pelvic anatomy. The pelvic incidence and lumbar lordosis may vary amongst different individuals, but their relationship is maintained to create sagittal balance in the lumbopelvic junction and maintain SVA in the global spine. Fixed sagittal deformities in the lumbar spine are often compensated by changes in pelvic and hip positioning, maintaining SVA.

PI is defined as the angle between a line drawn perpendicularly to the surface of the superior endplate of the sacrum and a line connecting the midpoint of the superior endplate of the sacrum to the center of the femoral head. The normal value for this measurement should be 55 +/- 10 degrees.

Pelvic Tilt

The angle between two of the following radiographic lines

A line from the center of the S1 endplate to the center of the femoral head A vertical line is drawn intersecting the center of the femoral head The normal value should be less than 20 degrees, can vary with patient positioning and contractures.

Assesment

Assessing sagittal balance involves a combination of clinical examination and radiographic analysis. Deviations from normal sagittal alignment can result from various conditions such as degenerative diseases, spinal deformities (like scoliosis), trauma, or post-surgical changes. Maintaining or restoring sagittal balance is often a goal in spine surgery to alleviate pain and improve function.

Clinical Importance

Pain Management: Imbalanced sagittal alignment can lead to chronic pain due to abnormal stress on the spine and surrounding muscles.

Postural Stability: Proper sagittal balance is essential for maintaining an upright posture without excessive muscular effort.

Surgical Outcomes: Preoperative assessment of sagittal balance can guide surgical planning and improve postoperative outcomes.

Diagnosis

For imaging, 36-inch standing films are the mainstay of spinal alignment imaging. It is critical to evaluate both the pelvis, femoral heads, and the spinal anatomy to illustrate the proper alignment, symmetry, and compensation. Certain measurements are vital.

The EOS X-ray system is a recent breakthrough in deformity correction imaging. It is a new technology that utilizes Nobel prize-winning concepts in particle detection, allowing 2D to 3D reconstructions from biplanar X-ray images. This machine allows for accurate measurement of spinal parameters in multiple planes, which is crucial in deformity surgery. The advantage of this imaging modality is that it confers 800-1000 times less radiation dose to the patient versus CT for the same

image.

CT and MRI may be introduced during surgical pre-operative investigation or evaluation of the patient's clinical disease. However, the mainstay of diagnosis remains plain films. It is important to remember the CT/MRI modalities are recombinant imaging platforms, not standing.

Treatment Approaches

Physical Therapy: Strengthening and stretching exercises to improve posture and support spinal alignment.

Bracing: In some cases, bracing may be used to correct or support spinal alignment.

Surgical Intervention: For significant deformities or imbalance, surgical options may include spinal fusion, osteotomies, or the use of instrumentation to restore alignment. Understanding and maintaining spine sagittal balance is crucial for spinal health, efficient movement, and overall quality of life.

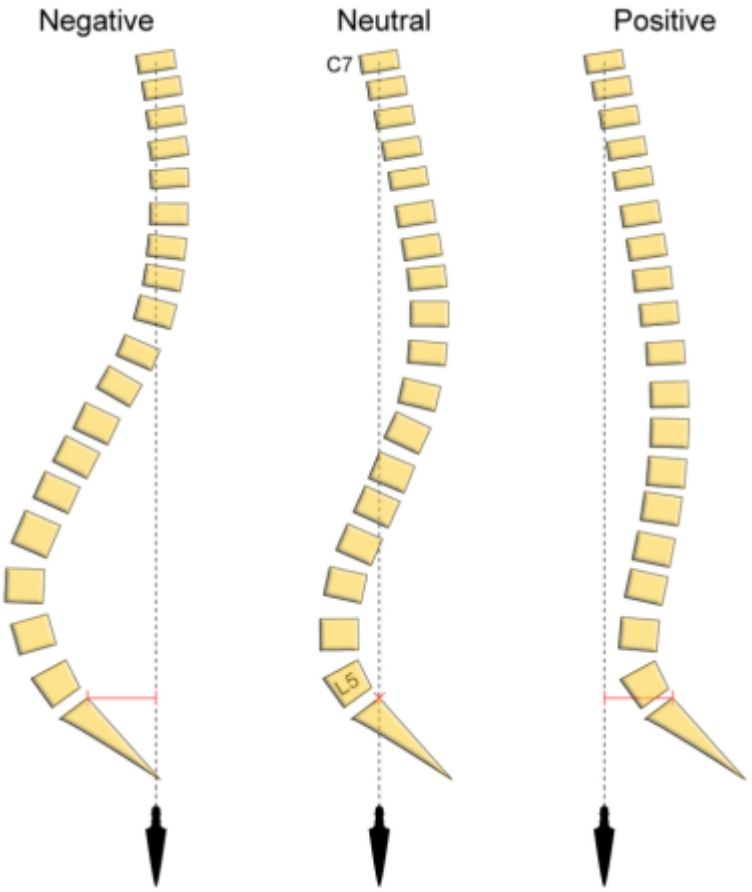
Outcome

Spine Sagittal Balance significantly affected the outcome of patients undergoing decompression surgery for lumbar spinal canal stenosis, the knowledge of which may serve better patient management [1].

Sagittal balance correlates with quality of life measures.

It is vital to preventing spine degeneration, as it can minimize energy expenditure by maintaining alignment. Several published articles discussed the relationship between pelvic incidence (PI) and degenerative lumbar disease, and they confirmed that such constant parameter in each individual was associated with orientation parameters of the lumbar spine or the thoracic spine, such as thoracic kyphosis or lumbar lordosis (LL) [2] [3] [4] [5] [6].

The sagittal balance of whole spine is affected critically in the clinical healthy state and optical biomechanical motion [7].



The analysis of the sagittal balance appeared to be essential in the management of lumbar degenerative pathologies, especially when a spinal fusion is achieved.

Sagittal balance in adult spinal deformity is a major predictor of quality of life. A temporary loss of paraspinal muscle force and somatic pain following spine surgery may limit a patient's ability to maintain posture.

A failure to recognise malalignment in this plane can have significant consequences for the patient not only in terms of pain and deformity, but also social interaction due to deficient forward gaze. A good understanding of the principles of sagittal balance is vital to achieve optimum outcomes when treating spinal disorders.

The Scoliosis research society (SRS) has previously described [8] normal sagittal balance as occurring when a plumb line drawn from the centre of the body of C7 lies within ±2 cm of the sacral promontory.

Different authors have described numerous indices for measuring changes in sagittal balance.

see Cervical sagittal balance.

Case series

2017

A retrospective review of a prospective observational database identified a consecutive series of patients with sagittal vertical axis (SVA) > 40 mm undergoing adult deformity surgery. Radiographic

parameters and clinical outcomes were measured out to 2 yr after surgery.

A total of 113 consecutive patients met inclusion criteria. Mean preoperative SVA was 90.3 mm, increased to 104.6 mm in the first week, then gradually reduced at each follow-up interval to 59.2 mm at 6 wk, 45.0 mm at 3 mo, 38.6 mm at 6 mo, and 34.1 mm at 1 yr (all P < .05). SVA did not change between 1 and 2 yr. Pelvic incidence-lumbar lordosis (PI-LL) corrected immediately from 25.3° to 8.5° (16.8° change; P < .01) and a decreased pelvic tilt from 27.6° to 17.6° (10° change; P < .01). No further change was noted in PI-LL. Pelvic tilt increased to 20.2° (P = .01) at 6 wk and held steady through 2 yr. Mean Visual Analog Scale, Oswestry Disability Index, and Short Form-36 scores all improved; pain rapidly improved, whereas disability measures improved as SVA improved.

Radiographic assessment of global sagittal alignment did not fully reflect surgical correction of sagittal balance until 6 mo after adult deformity surgery. Sagittal balance initially worsened then steadily improved at each interval over the first year postoperatively. At 1 yr, all clinical and radiographic measures outcomes were significantly improved [9].

2016

Farrokhi et al., performed a case-control study in which 48 patients with lumbar spine stenosis and 54 age- and sex-matched healthy subjects with back pain were eligible for participation. They used INFINITT picture archiving and communication systems (PACS) of the Chamran Hospital for selecting the patients for the study group. The sagittal balance, pelvic incidence, lumbar lordosis, and sacral slope were measured in all the patients and controls using thoracolumbosacral radiographies in the standing position.

There was no significant difference between the 2 groups regarding the baseline characteristics. The prevalence of sagittal imbalance was significantly higher in the patients with lumbar spine stenosis in comparison with the controls (31.2% vs. 14.8%; P<0.001). The sacral slope was significantly lower in patients with lumbar canal stenosis than the healthy controls (31.39°±11.2 vs. 43.7°±8.4; P<0.001). The lumbar lordosis was significantly lower in patients with lumbar canal stenosis than the controls (31.27°±12.4 vs. 45.8°±10.7; P < 0.001). The pelvic incidence was not significantly different between the 2 groups (50.16°±11.9 vs. 52°±9.6; P=0.342).

The degenerative lumbar canal stenosis is associated with increased sagittal imbalance and decreased lumbar lordosis and sacral slope in a sample of the Iranian adult population [10].

2015

Preoperative sagittal balance was not significantly correlated with clinical or HRQOL outcomes after decompression surgery in LCS patients without coronal imbalance. Decompression surgery improved the sagittal vertical axis (SVA) value in patients with preoperative sagittal imbalance; however, the patients with severe preoperative sagittal imbalance (SVA > 80 mm) had residual imbalance after decompression surgery. Both clinical and HRQOL outcomes were negatively affected by postoperative residual sagittal imbalance [11].

1)
Chang HS. Effect of Sagittal Spinal Balance on the Outcome of Decompression Surgery for Lumbar Canal Stenosis. World Neurosurg. 2018 Jul 20. pii: S1878-8750(18)31582-1. doi: 10.1016/j.wneu.2018.07.104. [Epub ahead of print] PubMed PMID: 30036716.

2)
Legaye J, Duval-Beaupere G, Hecquet J, et al. Pelvic incidence: A fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. Eur Spine J. 1998;7(2):99–103.
3)
Morvan G, Wybier M, Mathieu P, et al. [Plain radiographs of the spine: Static and relationships between spine and pelvis]. J Radiol. 2008;89(5 Pt 2):654–63.
4)
Berthonnaud E, Dimnet J, Roussouly P, et al. Analysis of the sagittal balance of the spine and pelvis using shape and orientation parameters. J Spinal Disord Tech. 2005;18(1):40–47.
5)
Weisz G, Houang M. Classification of the normal variation in the sagittal alignment of the human lumbar spine and pelvis in the standing position. Spine (Phila Pa 1976) 2005;30(13):1558–59.
6)
Boulay C, Tardieu C, Hecquet J, et al. Sagittal alignment of spine and pelvis regulated by pelvic incidence: Standard values and prediction of lordosis. Eur Spine J. 2006;15(4):415–22.
7)
Gore DR, Sepic SB, Gardner GM. Roentgenographic findings of the cervical spine in asymptomatic people. Spine (Phila Pa 1976) 1986;11:521–524.
8)
Scoliosis Research Society. White paper on sagittal plane alignment
9)
McDowell MM, Tempel ZJ, Gandhoke GS, Khattar NK, Hamilton DK, Kanter AS, Okonkwo DO. Evolution of Sagittal Imbalance Following Corrective Surgery for Sagittal Plane Deformity. Neurosurgery. 2017 Apr 10. doi: 10.1093/neuros/nyx145. [Epub ahead of print] PubMed PMID: 28402485.
10)
Farrokhi MR, Haghnegahdar A, Rezaee H, Sharifi Rad MR. Spinal sagittal balance and spinopelvic parameters in patients with degenerative lumbar spinal stenosis; a comparative study. Clin Neurol Neurosurg. 2016 Oct 31;151:136-141. doi: 10.1016/j.clineuro.2016.10.020. [Epub ahead of print] PubMed PMID: 27842292.
11)
Hikata T, Watanabe K, Fujita N, Iwanami A, Hosogane N, Ishii K, Nakamura M, Toyama Y, Matsumoto M. Impact of sagittal spinopelvic alignment on clinical outcomes after decompression surgery for lumbar spinal canal stenosis without coronal imbalance. J Neurosurg Spine. 2015 Jul 3:1-8. [Epub ahead of print] PubMed PMID: 26140404.