Volume: 25, Issue: 2, April 2014 pp.: 149-154

REVIEW ARTICLE / DERLEME

SAGITTAL PLANE ANALYSIS OF THE SPINE

OMURGANIN SAGİTTAL PLAN ANALİZİ

Yunus ATICI[1],
Mehmet Bülent BALİOĞLU[1],
Akif ALBAYRAK[1],
Deniz KARGIN[1],
Ayşegül ATICI[2],
Yunus Emre AKMAN[1]

[1]*Orthopedics and Traumatology Clinic, Metin Sabancı Baltalimanı Bone Diseases Training and Research Hospital, İstanbul, Turkey*
[2]*Physical Therapy and Rehabilitation Clinic, İstanbul Training and Research Hospital,, İstanbul, Turkey*

Address: Dr. Yunus Atıcı, Metin Sabancı Baltalimanı Kemik Hastalıkları Eğitim ve Araştırma Hastanesi, Ortopedi ve Travmatoloji Kliniği, Spine Disease Surgery and Prosthesis Surgery Group, Baltalimanı, Sarıyer / İSTANBUL
Tel.: 0505 4921945
E-mail: yunatici@hotmail.com
Received: 1st January, 2014
Accepted: 30th January, 2014

SUMMARY

With physiological and morphological changes during growth, the harmony between the pelvis and the spine continues. When this harmony is lost with sagittal plane deformities of the spine, we need to know the sagittal spinal and spinopelvic parameters to ensure restoration of the sagittal balance.

Key words: Sagittal balance, spinopelvic parameters, pelvic incidence

Level of Evidence: Review Article, Level V

ÖZET

Büyüme sırasında fizyolojik ve morfolojik değişikliklerle birlikte omurga ve pelvis arasında ki uyum devam etmektedir. Omurganın sagittal plan deformitelerinde bu uyumun kaybında; sagittal dengenin restorasyonunu sağlamak için sagittal spinal ve spinopelvik parametreleri bilmemiz gereklidir.

Anahtar Kelimeler: Sagittal denge, spinopelvik parametreler, pelvik insidans

Kanıt Düzeyi: Derleme, Düzey V

INTRODUCTION:

In pathological spinal deformities, we should know the sagittal spinal and spinopelvic parameters and their relationships, to provide balance. In sagittal X-rays, the cervical lordosis (CL), thoracic kyphosis (TK), lumbar lordosis (LL), sagittal vertical axis (SVA), pelvic tilt (PT), pelvic incidence (PI) and sacral slope (SS) are the main sagittal parameters that are evaluated. To evaluate these parameters properly, it is necessary to take a sagittal X-ray with a proper technique and to use suitable measurement methods.

SAGITTAL CONTOURS:

When measuring cervical lordosis (C2–7), the posterior tangent method is preferred due to its strong reliability[13]. The angle between lines drawn parallel to the posterior walls of the C2 and C7 vertebral bodies gives us the cervical lordosis. CL values of −5° or more, and CL values less than 0°, are defined as hypolordosis. Cervical kyphosis is seen when the values are more than 0° (Figure 1).

For TK (T2–12), the angle between the upper end plate of T2 and the lower end plate of T12 is measured with the Cobb method[1,2]. For LL (T12–S1), the angle between the lower end plate of T12 and the upper end plate of S1 is measured with the Cobb method (Figure-1). Lordosis values are defined as negative and kyphosis values are defined as positive. At the same time, the thoracolumbar sagittal alignment should be evaluated (the Cobb angle between the upper end plate of T10 and the lower end plate of L2)[2]. Sagittal spinal balance is normally characterized by cervical lordosis, thoracic kyphosis and lumbar lordosis. While thoracic kyphosis is normally between 10–40°, lumbar lordosis is between 40–60°[2].

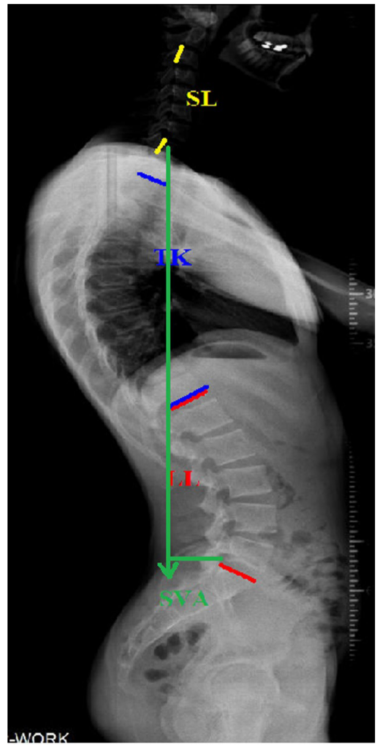

Figure-1. Yellow: Cervical lordosis (CL); Blue: Thoracic kyphosis (TK); Red: Lumbar Lordosis (LL); Green: Sagittal Vertical Axis (SVA)

According to the lumbopelvic anatomy defined by Legaye et al.[18], the three most commonly used parameters for pelvic sagittal analysis are PI, PT and SS (Figure-2). PT is defined as the angle between a line drawn towards the midline of the upper end plate of S1 and a vertical line drawn from the midpoint of a line formed by the connection of similar points on the center of the bicoxofemoral. SS is defined as the angle between the upper end plate of S1 and its horizontal axis. PI is defined as the angle between a vertical line drawn towards the upper end plate of S1 and a line drawn to the midpoint of the upper end plate of S1 from the midpoint of the line formed by the connection of similar points on the center of the bicoxofemoral axis.

At the same time, the sum of SS and PT gives PI. LL shows a direct correlation with PI. The sacropelvic parameters give information about the retroversion ability of the pelvis (in other words, pelvic compensation). They also help the surgeon in providing sagittal balance.

The sagittal vertical axis is evaluated according to the distance between a vertical line drawn downwards from the center of the C7 vertebral body and the postero-superior edge of the upper end plate of the S1 vertebral body. Sagittal balance is defined as when this line passes within a range from 2.5 cm anterior or posterior of the S1 postero-superior edge. If the line passes posteriorly to the edge of this range, it takes a negative value, and if it passes anteriorly, the value becomes positive[14].

DISCUSSION:

The sagittal vertical axis is inclined forwards in children, and a more negative sagittal vertical axis occurs with age. In a study by Cil et al., they stated that the sagittal vertical axis is related to lumbar lordosis. They observed an increase in LL and PI with age[9]. MacThiong et al. showed that a small increase occurred in PI with age, and this increase correlated with the increase in PT, while SS was relatively stable. They indicated that LL and PT tend to increase with age in order to maintain the sagittal balance during growth[19]. In another study by MacThiong et al., the strongest clinical relationship was shown between PI and LL[20]. While children grow, dynamic changes occur in the spinal sagittal balance and posture. These dynamic changes continue with aging.

The pelvis provides the main component for sagittal alignment. The spine and the pelvic structures are in harmony with each other to provide stability. While people with a large PI also have a large LL, people with a small PI have a small LL. Due to this correlation, the PI gives us information about what degree of LL should be given to obtain sagittal balance during deformity correction[22,26].

Sagittal balance is provided by the harmony of the spine, pelvis, hips and knees[15,23]. When this balance is obtained, the body spends minimum energy. Minimum energy usage continues due to maintenance of the harmony between the spine and pelvis with physiological and morphological changes during growth.

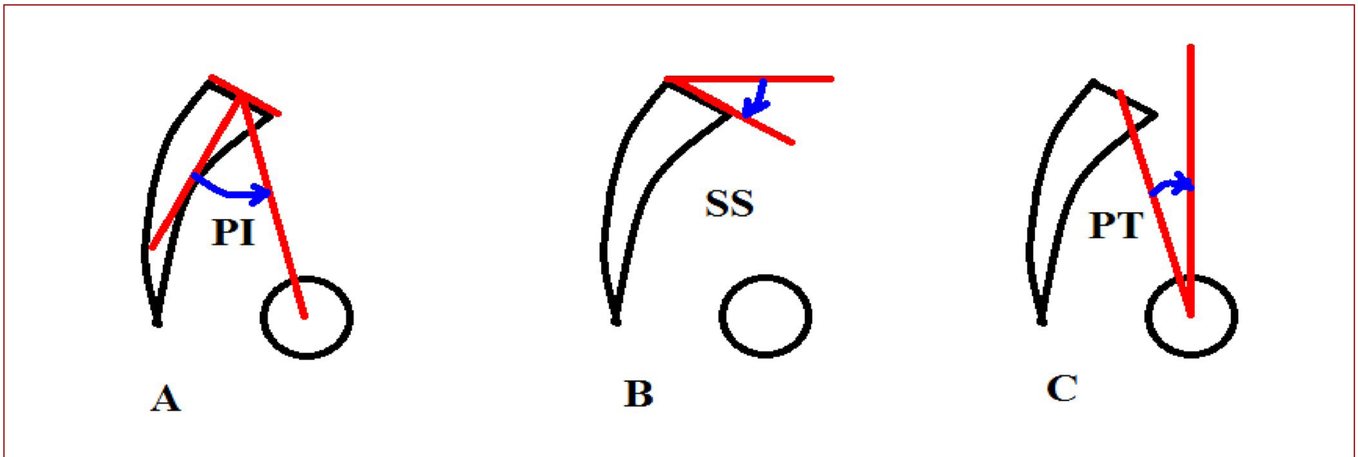

Figure-2. a. pelvic incidence (PI), **b.** sacral slope (SS), **c.** pelvic tilt (PT).

In patients with spine deformities that disrupt sagittal balance, postural changes occur to maintain the proper horizontal eye gaze. These adaptive changes include a reduction in pelvic tilt (pelvic retroversion), hip extension, knee flexion and hyperextension of cervical vertebrae[3,5,6]. While pelvic compensation is easier in the adolescent and childhood periods, the compensation ability of the pelvis decreases with age. Weak integration of the spinopelvic relationship can cause suboptimal situations or iatrogenic pathologies (flattening of the hip, proximal junction kyphosis, distal junction kyphosis, rigid sagittal imbalance and complications related to implants)[24]. In rigid situations occurring in the spine, sagittal balance cannot be provided by these adaptive changes. Therefore, a rigid sagittal imbalance can be defined as a disease-led clinical picture that means that the knee and hip cannot stand in an erect position without flexion, in order to compensate for the disrupted sagittal alignment resulting from loss of segmental lumbar lordosis[7,8]. Iatrogenic reasons commonly cause this situation (hypolordotic anterior or posterior fusion, pseudoarthrosis and kyphosis due to post-laminectomy). Other reasons can be post-traumatic, genetic (multilevel degenerative disc disease), congenital kyphoscoliosis and metabolic diseases (e.g. osteoporosis, ankylosing spondylitis and osteomalacia)[4,11,15,17]. In these pathological situations, the body requires supra-physiological energy to maintain an erect posture in order to prevent sagittal imbalance. This causes tiredness and pain in the paraspinal, hip and femur muscles of the spine[4,15,23]. When the body cannot maintain an erect posture, this results in disabilities due to being inclined forwards during walking, tripping and stumbling[10,11,12]. Further progression, or an acute deformity causing sagittal imbalance, causes a situation to develop that limits the social life, such as unbearable pain, an increase in pressure in the abdominal organs, arthrosis in the knee and hip with age, and difficulties with direct gaze[4].

Surgical techniques are needed to avoid these changes and to provide sagittal balance with the highest success rate. The desired amount of correction to provide sagittal balance with surgery is that the plumb line from the center of the C7 vertebra should pass over the upper end plate of the S1 vertebra[27].

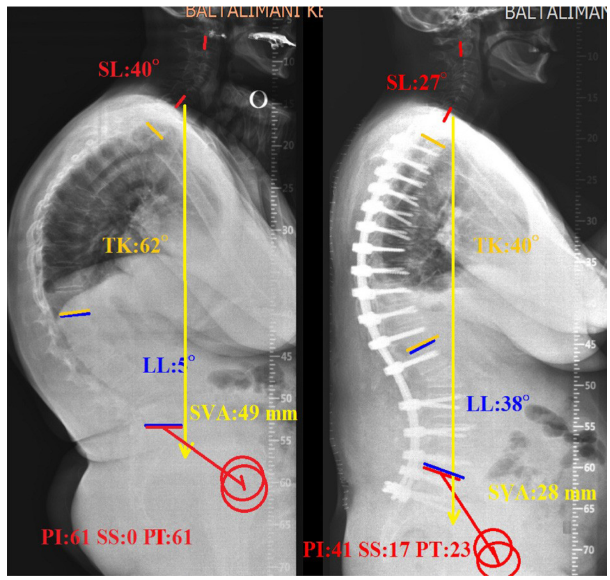

Figure-3. Female patient aged 55. Restoration of sagittal plan parameters by applying closed wedge osteotomy to the L2 vertebra of a case with a semi-rigid sagittal plane deformity.

Sagittal balance is defined as when this line passes inside a range from 2.5 cm anterior or posterior of the S1 postero-superior edge[14]. To bring the sagittal vertical axis within this range without symptoms or disability is the main aim of surgery. Therefore, Schwab et al. defined the optimal correction amounts of the sagittal plane parameters, as an aim for the management of sagittal deformity, as SVA < 50 mm, PT < 20° and PI–LL < 10° [25]. We also aim to reach these parameters to successfully treat our patients. For each of these parameters, planning of the surgical treatment should be carried out properly. In surgical treatment, flexibility of the deformity seems the most important criteria for restoration of the sagittal balance[15]. While sagittal balance can be provided with instrumentation only in flexible deformities (Scheuermann's kyphosis etc.), restoration of rigid deformities is performed by choosing one of the column shortening procedures (SPO, PSO, VCR) (Figure-3)[4,15,27]. With the help of one or more surgical techniques, it is necessary to re-design the sagittal balance of the spine and to maintain a capacity for direct looking by bringing the deformity within suitable thoracic kyphosis and lumbar lordosis limits[16,21].

REFERENCES

1. Bernhardt M, Bridwell KH: Segmental analysis of the sagittal plane alignment of the normal thoracic and lumbar spines and thoracolumbar junction. *Spine* 1989; 14: 717-721.

2. Berthonnaud E, Dimnet J, Labelle HB, Kuklo TR, O'Brien MF, Roussouly P: Spondylolisthesis, in O'Brien MF (ed): *Radiographic Measurement Manual*. Medtronic Sofamor Danek USA Inc, 2004; pp: 95-108.

3. Berven SH, Deviren V, Smith JA, Emami A, Hu SS, Bradford DS. Management of fixed sagittal plane deformity: results of the transpedicular wedge resection osteotomy. *Spine* 2001; 26: 2036–2043.

4. Boachie-Adjei O, Ferguson JA, Pigeon RG, Peskin MR. Transpedicular lumbar wedge resection osteotomy for fixed sagittal imbalance: surgical technique and early results. *Spine* 2006; 31: 485–492.

5. Booth KC, Bridwell KH, Lenke LG, Baldus CR, Blanke KM. Complications and predictive factors for the successful treatment of flatback deformity (fixed sagittal imbalance). *Spine* 1999; 24: 1712–1720.

6. Bradford DS, Tribus CB. Current concepts and management of patients with fixed decompensated spinal deformity. *Clin Orthop* 1994; 306: 64–72.

7. Bridwell KH, Lewis SJ, Rinella A, Lenke LG, Baldus C, Blanke K: Pedicle subtraction osteotomy for the treatment of fixed sagittal imbalance: Surgical technique. *J Bone Joint Surg* 2004; 86-A (suppl 1): 44-50.

8. Cho KJ, Bridwell KH, Lenke LG, et al. Comparison of Smith-Petersen versus pedicle subtraction osteotomy for the correction of fixed sagittal imbalance. *Spine* 2005; 30: 2030–2037.

9. Cil A, Yazici M, Uzumcugil A, Kandemir U, Alanay A, Alanay Y, Acaroglu RE, Surat A. The Evolution of Sagittal Segmental Alignment of the Spine During Childhood. *Spine 2*005; 30(1): 93-100.

10. Doherty JH. Complications of fusion in lumbar scoliosis: Proceedings of the Scoliosis Research Society. *J Bone Joint Surg* 1973; 55-A: 438.

11. Farcy JP, Schwab FJ. Management of flatback and related kyphotic decompensation syndromes. *Spine* 1997; 22: 2452-2457.

12. Grobler LJ, Moe JH, Winter RB. Loss of lumbar lordosis following surgical correction of thoracolumbar deformities. *Orthopaedic Transactions* 1978; 239: 2-11.

13. Harrison DE, Harrison DD, Cailliet R, Troyanovich SJ, Janik TJ, Holland B. Cobb method or Harrison posterior tangent method: which to choose for lateral cervical radiographic analysis. *Spine* 2000; 25(16): 2072-2078.

14. Jackson RP, McManus AC. Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size: A prospective controlled clinical study. *Spine* 1994; 19: 1611-1618.

15. Joseph SA Jr, Moreno AP, Brandoff J, Casden AC, Kuflik P, Neuwirth MG. Sagittal plane deformity in the adult patient. *J Am Acad Orthop Surg* 2009; 17(6): 378-388. Review.

16. Kiaer T, Gehrchen M. Transpedicular closed wedge osteotomy in ankylosing spondylitis: results of surgical treatment and prospective outcome analysis. *Eur Spine J* 2010; 19: 57–64.

17. Kim KT, Lee SH, Suk KS, Lee JH, Jeong BO. Outcome of pedicle subtraction osteotomies for fixed sagittal imbalance of multiple etiologies: a retrospective review of 140 patients. *Spine* 2012; 37: 1667–1675.

18. Legaye J, Duval-Beaupère G, Hecquet J, Marty C. Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. *Eur Spine J* 1998; 7(2): 99-103.

19. Mac-Thiong JM, Berthonnaud E, Dimar JR 2nd, Betz RR, Labelle H. Sagittal alignment of the spine and pelvis during growth. *Spine* 2004; 29(15): 1642-1647.

20. Mac-Thiong JM, Labelle H, Roussouly P. Pediatric sagittal alignment. *Eur Spine J* 2011; 20 Suppl 5: 586-590. Review.

21. Pigge RR, Scheerder FJ, Smit TH, Mullender MG, van Royen BJ. Effectiveness of preoperative planning in the restoration of balance and view in ankylosing spondylitis. *Neurosurg Focus* 2008; 24: E7.

22. Roussouly P, Pinheiro-Franco JL. Biomechanical analysis of the spino-pelvic organization and adaptation in pathology. *Eur Spine J* 2011; 20 (suppl.-5): 609–618 .

23. Schwab F, Lafage V, Boyce R, Skalli W, Farcy JP. Gravity line analysis in adultvolunteers: Age-related correlation with spinal parameters, pelvic parameters, and foot position. *Spine* 2006; 31: E959-E967.

24. Schwab F, Lafage V, Patel A, Farcy JP. Sagittal Plane Considerations and the Pelvis in the Adult Patient. *Spine* 2009; 34(17): 1828-1833. Review.

25. Schwab F, Patel A, Ungar B , Farcy JP, Lafage V. Adult spinal deformity-postoperative standing imbalance: how much can you tolerate? An overview of key parameters in assessing alignment and planning corrective surgery. *Spine* 2010; 35: 2224–2231.

26. Qian BP, Jiang J, Qiu Y, Wang B, Yu Y, Zhu ZZ. Radiographical predictors for postoperative sagittal imbalance in patients with thoracolumbar kyphosis secondary to ankylosing spondylitis after lumbar pedicle subtraction osteotomy *Spine* 2013; 38(26): E1669-E1675.

27. Zhang HQ, Huang J, Guo CF, Liu SH, Tang MX. Two-level pedicle subtraction osteotomy for severe thoracolumbar kyphotic deformity in ankylosing spondylitis. *Eur Spine J* 2014; 23(1): 234–241.