ACTA
ORTHOPAEDICA
et
TRAUMATOLOGICA
TURCICA

Acta Orthop Traumatol Turc 2010;44(4):300-305
doi:10.3944/AOTT.2010.2391

Is there any correlation between the preoperative parameters and correction loss in patients operated for hyperkyphosis?

Murat TONBUL, Osman ORMAN, Mehmet Reşat YILMAZ, Müjdat ADAŞ, H. Cihangir YURDOĞLU, Egemen ALTAN

İstanbul Okmeydanı Training and Research Hospital, Department of Orthopedics and Traumatology, İstanbul

Objectives: Preoperative, postoperative, and latest follow-up data of sagittal balance and spinopelvic parameters of our patients treated surgically for hyperkyphosis were evaluated retrospectively, to determine whether there is any correlation between the preoperative pelvic incidence and postoperative correction loss.

Methods: Totally 33 patients (18 females) who were operated for hyperkyphosis and, were reached at the latest follow-up were included in the study. Age at operation, gender, date of operation, etiology and level of the deformities, instrumentation, and graft types were noted in detail. The kyphosis angles were measured by the Cobb method. The preoperative and postoperative spinopelvic parameters (pelvic incidence, sacral slope, and pelvic tilt) were recorded.

Results: The average follow-up was 4 years (range 3-8 years). The mean age at operation was 21 years (range 14-40 years). Scheuermann kyphosis was diagnosed as the etiological factor in 18 patients (53%). The mean preoperative kyphosis angle was 76° (range 55-98°), which decreased postoperatively to 38° (range 20-55°) ($p<0.05$). The mean kyphosis angle two years postoperatively was 41° ($p>0.05$). Preoperative and latest follow-up spinopelvic parameters were also not significantly different. Furthermore, no correlation could be found between the age at operation, instrumentation level, spinopelvic parameters, and correction loss.

Conclusion: There is no correlation between the preoperative pelvic incidence and postoperative correction loss in patients treated surgically for hyperkyphosis. Further studies with larger sample size and longer follow-up should be conducted.

Key words: Hyperkyphosis; spinopelvic parameters; vertebral correction.

The spine has the two contrasting characteristics—strength and flexibility. The structure of the human spine ensures and maintains physiologic posture using minimal energy. Pathology involving the frontal and sagittal planes increases the energy that the spine must expend to maintain its posture, and increases the burden on the vertebrae, muscles, and ligaments, leading to early degeneration of the spinal joints, excess tension in the paravertebral muscles, and compensatory changes in the pelvis and lower extremities.

Studies performed on the spine in the sagittal plane have increased since the 1970s. In general, these studies have investigated the normal values for thoracic kyphosis and lumbar lordosis, the correlation

Correspondence: Murat Tonbul, MD. İstanbul Okmeydanı Eğitim ve Araştırma Hastanesi, Ortopedi ve Travmatoloji Kliniği, Darülaceze Cad. No: 25, Şişli, İstanbul. Tel: +90 212 - 314 55 55 e-mail: dr_mtonbul@hotmail.com

Submitted: December 3, 2009 **Accepted:** April 14, 2010

of these values with each other and with the balance of the entire spine, and their association with age and gender.[1-5] These studies included healthy individuals, patients with degenerative disease, and patients with spondylolisthesis. We have identified no study addressing the question of whether there is any correlation between preoperative pelvic incidence and correction loss in patients with hyperkyphosis.

Our study was based on sagittal balance values and preoperative, postoperative, and final spinopelvic parameters obtained retrospectively for the patients operated for hyperkyphosis. We aimed to determine whether there is a correlation between preoperative pelvic incidence and postoperative correction losses.

Patients and methods

The study enrolled a total of 33 patients (18 females and 15 males) who underwent surgery to treat hyperkyphosis between January 2003 and January 2010 at our clinic. Each enrolled patient had a complete medical record, and attended the final follow-up visits. All patients had posterior instrumentation and fusion. In addition, two patients had anterior fusion.

The patients were examined clinically and radiologically preoperatively, every 6 months in the postoperative period, and at the final visit (48 months postoperatively). Anteroposterior and lateral height radiographs were taken in a standing position, to measure the angle of kyphosis, pelvic incidence, sacral declination, and pelvic tilt angle. All measurements were obtained using the same goniometer, but by two different experienced investigators.

During the processing of the patient data, the correlation analyses, Pearson and Spearman, were used. Thoracic kyphosis angles and spinopelvic parameters obtained before and after the operation and during the follow-up were statistically evaluated using the paired t-test. P values <0.05 were considered statistically significant.

Results

The mean follow-up duration of the patients was 4 years (range 3-8 years). The mean age of the patients at the time of operation was 21 years (range 14-40 years). Mean age was 22 years (range 14-40 years) for women and 20 years (range 15-40 years) for men. Of the patients who participated in the study, 18 (53%) had Scheuermann kyphosis, four (15%) had kyphosis due to Marfan syndrome, one (3%) had post-traumatic kyphosis, and 10 (29%) had idiopathic kyphosis. Such variability in our sample is a weakness in our study. Results obtained from a more uniform sample would be more informative for planning the treatment of the patients with kyphosis of the same etiology; however, because of the limited number of patients with this degree of kyphosis, we enrolled patients with kyphosis due to a variety of etiologies. The site of deformity was the thoracic vertebrae in 22 patients (67%) and thoracolumbar vertebrae in 11 patients (33%).

All patients who participated in our study underwent a posterior instrumentation with a hybrid system. Two of our patients underwent anterior fusion in addition to posterior instrumentation and fusion. With posterior instrumentation, we used a polyaxial closed pedicular screw and hook system on 17 patients (52%), and a mono-axial closed pedicular screw and hook system on 16 patients (48%).

In our patients, fusion was performed using an allograft in 24 patients (72%) and synthetic grafts (tricalcium phosphate) in nine patients (28%). Both synthetic and allograft material was mixed with autograft material obtained from spinous protuberances and laminar decortications. In patients who participated in our study, we did posterior instrumentation and fusion on a segment containing an average of 13.7 vertebrae, with segments ranging from seven vertebrae (T9-L3), to 15 vertebrae (T2-L4).

Before the operation, the mean thoracic kyphosis angle of our patients was 76° (range 55-98°). Postoperatively, we observed that the mean thoracic kyphosis angle was reduced to 38° (range 20-55°) ($p<0.05$). Six months postoperatively, the mean thoracic kyphosis angle was 38.5° showing an increase of 0.29°. At one year, the mean thoracic kyphosis angle was 40°, showing an increase of 1.80°. At two years, the mean thoracic kyphosis angle was 41°, showing an increase of 3.03° ($p>0.05$) (Fig. 1).

We found that our patients showed a mean improvement of 37.5° (range 19-58°) with the operation. At the same time, in our patients, the mean angles of pelvic incidence, sacral inclination, and pelvic tilt were 42° (range 24-64°), 31° (range 18-37°), and 8° (range 3-23°), respectively. These val-

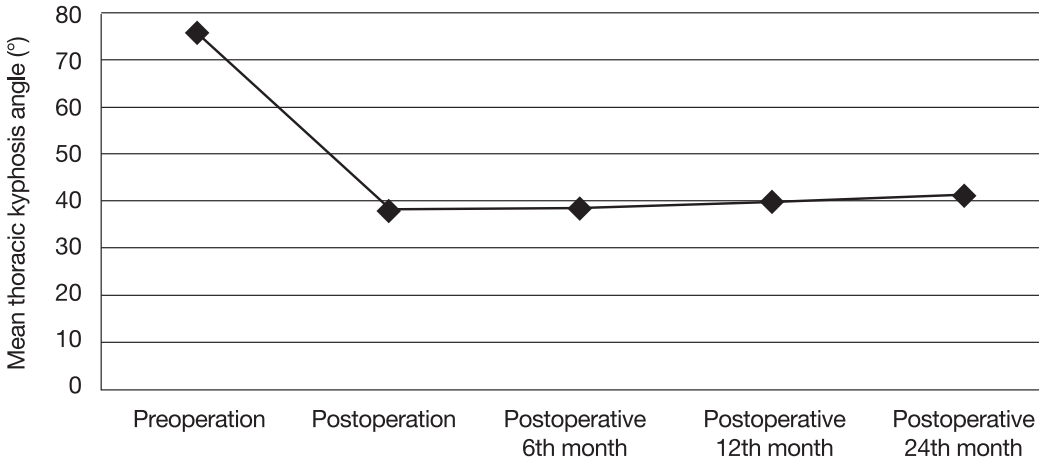

Fig. 1. The change of mean thoracic kyphosis angle over time.

ues were calculated as 43° (range 25-60°), 33.5° (range 20-40°) and 9.5° (range 2-25°), respectively, during the final visit ($p>0.05$).

No significant correlation was found between the age of the patients and the correction loss (Table 1). No correlation was found between the range of instrumentation and the correction loss obtained at the end of the second year. We investigated a linear or non-linear, significant, proportional, or inverse correlation between the preoperative pelvic incidence angle and the correction loss. In the statistical correlation analysis performed after excluding two patients who had extreme values, no correlation was found between pelvic incidence angle and the correction loss obtained at the end of the second year (Table 1). No significant correlation was found between other spinopelvic parameters, sacral inclination angle and pelvic tilt angle, and the correction loss during the statistical studies based on the correlation analysis performed (Table 1).

The patients' complaints on presentation included back pain and kyphosis, in order of frequency. These symptoms were followed by neck and lower back pain. We observed that, postoperatively, the complaints had resolved in all, but two patients. After the operation, both of these patients complained of numbness in their hands, and stated that they used GABA inhibitors continuously. The electrophysiological studies and radiological examinations performed on both of these patients did not reveal any findings that would explain this situation. They were advised to continue to their drug therapy under the supervision of a neurologist.

Table 1

Correlation between age and preoperative spinopelvic parameters, and correction loss (n=31)

	Pearson correlation		Spearman's correlation	
	r	p value	r	p value
Age	0.036	0.849	0.054	0.771
Preoperative spinopelvic parameters				
Pelvic incidence angle	0.029	0.878	0.157	0.399
Sacral inclination angle	-0.046	0.804	0.157	0.399
Pelvic tilt angle	0.092	0.621	0.044	0.814

Discussion

When thoracic kyphosis exceeds the normal limits of physiological kyphosis, this results in anterior deviation of the sagittal balance line. Similarly, anterior deviation may result in secondary thoracic kyphosis. It has been observed by several investigators that there is a correlation between lumbar lordosis and sacral inclination angles.[1,6,7] The diseases that influence the lumbar vertebrae or the sacropelvic junction lead to compensatory modifications such as an increase or a decrease in thoracic kyphosis, by impairing the sagittal balance.

Radiologically, the thoracic kyphosis angle is the angle between the upper surface of the first thoracic vertebra and the lower surface of the twelfth thoracic vertebra. In the studies performed, the measurements performed using Cobb method in the patients with scoliosis deformity showed that there might be an error of 3.9-12.6°.[8-10] Dimar et al.[11] investigated the inter-observer, inter-measurement, and computerized changes observed in spinal and pelvic angles, and reported that computerized tools of measurement were the most precise method with the smallest error ratio. In the measurement of our subjects' angles, the coefficient of the measurement differences between measurements by different observers, and between measurements at different times was found to be 0.9.

Mean physiological kyphosis value was considered to be 20-40°, and was reported to increase in proportion to age.[10,12-17] Between the 5th and 20th years of the life, thoracic kyphosis angle shows a linear increase, and no difference is found between genders. In patients with spondylolisthesis, the thoracic kyphosis angle decreases.[2,16,17] In our subjects, we found that the mean pre-operative thoracic kyphosis angle was 76° (range 55-98°).

In the analysis of the sacropelvic junction, anatomic and positional parameters are used. The main positional parameters are lumbosacral angle, L5 incidence angle, pelvic tilt angle, and sacral inclination angle (Fig. 2).[18] Anatomic parameters are sacral inclination and pelvic inclination. Although these parameters are used to evaluate different sites, they are associated, and interact with each other. When there is a change in a site or in a parameter, other parameters form a compensatory response to restore the sagittal balance.

Pelvic tilt angle is the angle between the line joining the midpoint of the upper surface of the sacrum and the midpoint of the femoral heads and the vertical line passing from the midpoint of the femoral heads (Fig. 2). It is reported that in the healthy population, pelvic tilt angle varies between 12.1 and 13.2°.[17,19-21] When lumbar lordosis is reduced, pelvic tilt angle increased, due to the pelvis that is inclined posteriorly. In addition, in patients with flexion contracture, pelvic tilt angle is increased. Pelvic tilt angle is higher in patients with spondylolisthesis than in the normal population, and pelvic tilt angle increases with the increasing angle of spondylolisthesis. This value was calculated to be 9.5° on average (range 2-25°) in our patients.

The sacral inclination angle is the angle between the line parallel to the upper surface of the sacrum and the horizontal line drawn from the upper posterior edge of the sacrum (Fig. 2). It is reported that in healthy adults, sacral inclination angle varies between 39.4° and 41.2°.[14,17,19,20,22] Lumbar vertebrae, the spinopelvic junction, and the hip joint influence the sacral inclination angle.

Sacral inclination angle is proportionally correlated with the angles of pelvic incidence, lumbar lordosis, and thoracic kyphosis. With decreasing lumbar lordosis, as a compensatory change, the pelvis turns to posterior around the hip axis, the sacrum becomes more vertical, and sacral inclination angle diminishes. When the pelvic incidence angle increases, the sacral inclination angle increases as well. In the

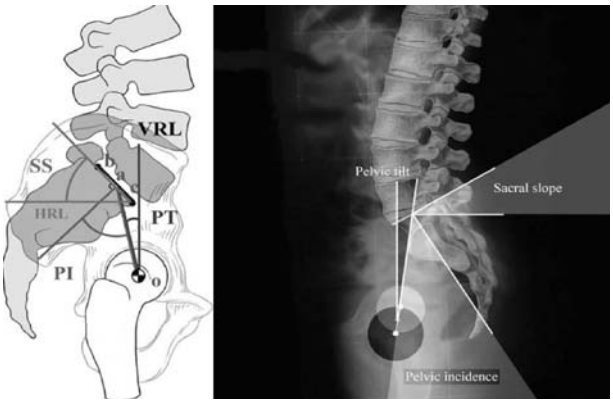

Fig. 2. The measurement methods for pelvic incidence **(PI)**, sacral inclination **(SS)** and pelvic tilt **(PT)** angles.[18] **HRL:** Horizontal reference line, **VRL:** Vertical reference line.

patients with spondylolisthesis, the sacral inclination angle is increased. This value was calculated to be 33.5° on average (range 20-40°) in our patients.

Pelvic incidence angle is the angle between the line drawn perpendicular to the upper surface of the sacrum from the midpoint of the upper surface of the sacrum, and the line that joins the femoral head to the upper surface of the sacrum (Fig. 2). In addition, pelvic incidence angle may be calculated with the following formula: "pelvic incidence angle = pelvic tilt angle + sacral inclination angle" (PI=PT+SS). Vialle et al.[21] reported a pelvic incidence angle of 54.7±10.6° in the analysis that they performed on 300 healthy adults with a mean age of 35 years. They measured pelvic incidence angle as 53.2±10.3° in men, and 48.2±7° in women. Duval-Beaupère et al.[3] reported pelvic incidence angle as 51.8° in the analysis that they performed on 11 healthy men with a mean age of 29.7, and 6 healthy women with a mean age of 29 years. When pelvic incidence angle diminishes, the force arm of the extensor muscles of the hip becomes shorter and thereby, flexion contracture may occur. The more the spondylolisthesis angle increases, the more the pelvic incidence angle increases. There is a correlation between pelvic incidence and sacral inclination and pelvic tilt angle. This value was calculated to be 43° on average (range 25-60°) in our patients.

It is known that the morphology of the pelvis strongly influences the sagittal spinal geometry and, especially, the lumbar lordosis.[13] The progression of the spinal deformities and the effect of pelvic morphology on the spinal balance during the treatment of spinal deformities should be well understood. It is general knowledge that modifications of spinopelvic balance are compensated to give a stable pelvic incidence angle, with the changes that will occur in pelvic tilt and sacral inclination angles. Theoretically, pelvic incidence angle is stable.

In the study that Mac-Thiong et al.[19] conducted on children and adolescents, they investigated the correlations between thoracic kyphosis, lumbar lordosis, pelvic incidence, sacral inclination, and pelvic tilt. They found a moderate correlation between thoracic kyphosis and lumbar lordosis, and a marked correlation between sacral inclination and lumbar lordosis. No direct correlation was found between pelvic incidence and thoracic kyphosis. In a study performed by Gottfried et al.[23] an increase of pelvic incidence and pelvic tilt, and a decrease of lumbar lordosis were found in the patients with a flat back of iatrogenic etiology. This compensatory mechanism prevents an increase of kyphosis. In a study performer by Cheng et al.[24] it was reported that in healthy individuals, spinopelvic balance should be TK+LL+PI <45°.

In summary, in our series of 33 patients, no correlation was found between age at the time of the operation, the range of instrumentation, pelvic incidence, sacral inclination, and pelvic tilt; and the correction loss.

Consequently, the answer that we found for the main question of our study, "In the patients operated due to hyperkyphosis, is there a correlation between pre-operative spinopelvic parameters and the correction loss?" is negative. Moreover, our observed correction loss is not statistically significant. Previous publications were based on samples that included healthy individuals, subjects with degenerative disease, and subjects with spondylolisthesis. No study performed to date sought (or found) an answer to this question. Further studies may be conducted to determine whether a more uniform and larger study group, and a longer duration of follow-up may provide a positive answer for this question. Osteoporosis and correction loss that may occur in the patients with advanced age, and their correlations with spinopelvic parameters may be determined by performing a longer clinical and radiological follow-up. Therefore, the present study, performed as a pre-evaluation, continue to follow the study patients.

References

1. Stagnara P, De Mauroy JC, Dran G, Gonon GP, Costanzo G, Dimnet J, et al. Reciprocal angulation of vertebral bodies in a sagittal plane: approach to references for the evaluation of kyphosis and lordosis. Spine (Phila Pa 1976) 1982;7:335-42.
2. Voutsinas SA, MacEwen GD. Sagittal profiles of the spine. Clin Orthop Relat Res 1986;(210):235-42.
3. Duval-Beaupère G, Schmidt C, Cosson P. A Barycentremetric study of the sagittal shape of spine and pelvis: the conditions required for an economic standing position. Ann Biomed Eng 1992;20:451-62.

4. 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 (Phila Pa 1976) 1994;19:1611-8.
5. Gardocki RJ, Watkins RG, Williams LA. Measurements of lumbopelvic lordosis using the pelvic radius technique as it correlates with sagittal spinal balance and sacral translation. Spine J 2002;2:421-9.
6. Vedantam R, Lenke LG, Bridwell KH, Linville DL, Blanke K. The effect of variation in arm position on sagittal spinal alignment. Spine (Phila Pa 1976) 2000;25:2204-9.
7. Vedantam R, Lenke LG, Keeney JA, Bridwell KH. Comparison of standing sagittal spinal alignment in asymptomatic adolescents and adults. Spine (Phila Pa 1976) 1998;23:211-5.
8. Carman DL, Browne RH, Birch JG. Measurement of scoliosis and kyphosis radiographs. Intraobserver and interobserver variation. J Bone Joint Surg Am 1990;72:328-33.
9. Gelb DE, Lenke LG, Bridwell KH, Blanke K, McEnery KW. An analysis of sagittal spinal alignment in 100 asymptomatic middle and older aged volunteers. Spine (Phila Pa 1976) 1995;20:1351-8.
10. Korovessis PG, Stamatakis MV, Baikousis AG. Reciprocal angulation of vertebral bodies in the sagittal plane in an asymptomatic Greek population. Spine (Phila Pa 1976) 1998;23:700-5.
11. Dimar JR 2nd, Carreon LY, Labelle H, Djurasovic M, Weidenbaum M, Brown C, Roussouly P. Intra- and interobserver reliability of determining radiographic sagittal parameters of the spine and pelvis using a manual and a computer-assisted methods. Eur Spine J 2008;17:1373-9.
12. Berthonnaud E, Dimnet J, Roussouly P, Labelle H. Analysis of the sagittal balance of the spine and pelvis using shape and orientation parameters. J Spinal Disord Tech 2005;18:40-7.
13. Hardacker JW, Shuford RF, Capicotto PN, Pryor PW. Radiographic standing cervical segmental alignment in adult volunteers without neck symptoms. Spine (Phila Pa 1976) 1997;22:1472-80.
14. Jackson RP, Hales C. Congruent spinopelvic alignment on standing lateral radiographs of adult volunteers. Spine (Phila Pa 1976) 2000;25:2808-15.
15. Jackson RP, Kanemura T, Kawakami N, Hales C. Lumbopelvic lordosis and pelvic balance on repeated standing lateral radiographs of adult volunteers and untreated patients with constant low back pain. Spine (Phila Pa 1976) 2000;25:575-86.
16. Jackson RP, Phipps T, Hales C, Surber J. Pelvic lordosis and alignment in spondylolisthesis. Spine (Phila Pa 1976) 2003;28:151-60.
17. Labelle H, Roussouly P, Berthonnaud E, Transfeldt E, O'Brien M, Chopin D, et al. Spondylolisthesis, pelvic incidence, and spinopelvic balance: a correlation study. Spine (Phila Pa 1976) 2004;29:2049-54.
18. O'Brien MF, Kuklo TR, Blanke KM. Radiographic measurement manual: spinal deformity study group. Memphis: Medtronic Sofamor Danek; 2004.
19. Mac-Thiong JM, Labelle H, Berthonnaud E, Betz RR, Roussouly P. Sagittal spinopelvic balance in normal children and adolescents. Eur Spine J 2007;16:227-34.
20. Vaz G, Roussouly P, Berthonnaud E, Dimnet J. Sagittal morphology and equilibrium of pelvis and spine. Eur Spine J 2002;11:80-7.
21. Vialle R, Levassor N, Rillardon L, Templier A, Skalli W, Guigui P. Radiographic analysis of the sagittal alignment and balance of the spine in asymptomatic subjects. J Bone Joint Surg Am 2005;87:260-7.
22. Vialle R, Ilharreborde B, Dauzac C, Guigui P. Intra and inter-observer reliability of determining degree of pelvic incidence in high-grade spondylolisthesis using a computer assisted method. Eur Spine J 2006;15:1449-53.
23. Gottfried ON, Daubs MD, Patel AA, Dailey AT, Brodke DS. Spinopelvic parameters in postfusion flatback deformity patients. Spine J 2009;9:639-47.
24. Cheng I. Point of view: spinopelvic parameters in postfusion flatback deformity patients. Spine J 2009;9:672-3.