Increasing pelvic incidence is associated with more global sagittal imbalance in ankylosing spondylitis with thoracolumbar kyphosis

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Research article

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Abstract

Background: Ankylosing spondylitis (AS) patients with kyphosis have an abnormal spinopelvic alignment and pelvic morphology. Most of them focus on the relationship of pelvic tilt (PT) or sacral slope (SS) and deformity, and relatively few studies have addressed the relationship between pelvic incidence (PI) and kyphosis in AS patients. The purpose of this study is to analyze the correlation between pelvic incidence (PI) and the spinopelvic parameters describing local deformity or global sagittal balance in AS patients with thoracolumbar kyphosis.

Methods: A total of 94 patients with AS (91 males and 3 females) and 30 controls were reviewed. Sagittal spinopelvic parameters, including PI, PT, SS, thoracic kyphosis (TK), thoracolumbar kyphosis (TLK), lumbar lordosis(LL), sagittal vertical axis(SVA), T1 pelvic angle(TPA), spinosacral angle(SSA) and spinopelvic angle(SPA) were measured. Statistical analysis was performed to identify the correlation of PI with other parameters.

Results: Compared with the control group, the AS patients had significantly higher PI(47.4° vs. 43.2° , $P<0.001$). PI in AS patients was found to be significantly positively correlated with TPA($r=0.533$, $R^2=0.284$, $P<0.001$), and negatively correlated with SPA($r=-0.504$, $R^2=0.254$, $P<0.001$). However, no correlations were found between PI and SVA, SSA, TK, TLK or LL in AS patients.

Conclusion: The value of PI in AS patients with kyphosis was significantly higher than that of controls. Correlation analysis revealed that increasing PI was significantly correlated with more global sagittal imbalance, not with the local deformity in AS patients with thoracolumbar kyphosis.

Background

Ankylosing spondylitis (AS) is a chronic, inflammatory rheumatic disease that primarily involves the axial skeleton, which can cause characteristic rigid thoracolumbar kyphosis(TLK) in the latter stage, leading to sagittal spinopelvic imbalance and impairing the patient's horizontal gaze and activities of daily living[1, 2]. For those AS patients with severe kyphotic deformity, corrective spinal osteotomy is usually necessary.

In recent years the sagittal morphology of the spine and pelvis has become one of the most focused topics in spinal deformity research. Pelvic incidence (PI) is an individual and position-independent anatomic spinopelvic parameter[3–5]. Previous studies have shown that abnormal PI is a risk factor for sagittal imbalance of the spine and may be related to certain spinal pathology[6–8]. PI also determines the ability of the compensation for the spinal deformity by pelvic retroversion[9], which is the major accommodation of kyphotic deformity[10]. For AS patients with kyphosis, the accurate angle required for spinal osteotomy can be calculated based on the value of PI[1]. Besides, PI and lumbar lordosis (LL) mismatching can also be applied in the evaluation of the surgical outcomes in AS patients with kyphosis[11].

Several studies have demonstrated that AS patients with kyphosis have an abnormal spinopelvic alignment and pelvic morphology[12–16]. Most of them focus on the relationship of pelvic tilt (PT) or sacral slope (SS) and deformity, and relatively few studies have addressed the relationship between PI and kyphosis in AS patients. Debarge et al.[12] reported that PI in AS patients was significantly higher compared with normal control group. While Lee et al.[13] found that PI was lower in AS patients and the positive correlation was observed between PI with the spinosacral angle (SSA)[17], a parameter assessing the whole deformity, which indicated that AS patients with lower PI had a greater risk of sagittal imbalance. However, their results also showed that PI was higher in sagittal imbalance group than that in sagittal balance group[13]. Therefore, we consider that a more comprehensive understanding of relationship between PI and AS is needed, which would be useful for assessment of deformity and surgical planning in AS patients with kyphosis. The purpose of this study is to analyze the correlation between PI and the spinopelvic parameters describing local deformity or global sagittal balance in AS patients with thoracolumbar kyphosis.

Methods

We performed a retrospective study of consecutive patients with AS who underwent spine surgery at our institution between January 2012 and December 2017. All AS patients met the most recent modified New York criteria[18]. The inclusion criteria were (1) Type II (thoracolumbar) kyphosis[19], (2) no scoliosis or with a coronal curve $<10^\circ$, and (3) no hip flexion contractures. The exclusion criteria were (1) previous spine, hips or lower extremity surgery, (2) preoperative infection of the spine and (3) preoperative spinal fractures. Therefore, this study included 94 AS patients (91 males and 3 females) with a mean age of 36.8 years old(range 21 to 65). Thirty normal subjects were recruited as control group, who underwent full-length spine radiography during health check-up. The present study was approved by the Clinical Research Ethics Committee of our institution.

Full-length spine radiographs including the whole spine and pelvis of AS patients who were standing in a natural position were taken preoperatively. The following radiographical parameters were assessed: PI, the angle between the line perpendicular to the sacral plate at its midpoint and the line connecting this point to the axis of the femoral heads; PT, the angle between the line linking the midpoint of the sacral plate with the femoral head axis and the vertical axis; SS, the angle between the sacral plate and the horizontal line; thoracic kyphosis (TK), the angle between the upper end plate of T4 and the lower end plate of T12; TLK, the angle between the upper end plate of T11 and the lower end plate of L2; LL, the angle between the upper end plate of L1 and the upper end plate of S1; sagittal vertical axis (SVA), the distance between the C7 plumb line (C7PL) and the posterosuperior corner of S1; T1 pelvic angle (TPA)[20], the angle between the line from the center of the femoral heads to the center of T1 vertebral body and the line from the center of the femoral heads to the center of the superior sacral endplate; SSA[12, 17], the angle between the sacral endplate and the line connecting the midpoint of the sacral endplate and the center of C7 vertebral body; and spinopelvic angle(SPA)[17], the angle between a line from the center of C7 to the center of the sacral endplate and a line from the center of the sacral endplate to the center of the femoral heads. For TK, TLK and LL, the angle was negative if the curve was lordotic and

was positive if the curve was kyphotic. Surgimap (New York, NY, USA) was used to measure all the parameters. All measurements were performed twice independently by 3 spine surgeons with an interval of 2 weeks between measurements.

Statistical Analysis

The statistical analyses was performed using IBM SPSS (version 24, IBM Corp.). Continuous variables were presented as the means $\pm$ standard deviations. The two groups were compared with the Student's t-test and the chi-square test. Pearson correlation (r) and a linear regression model were used where appropriate.

Results

Mean age and gender ratios were similar in AS group and control group. The sagittal spinopelvic parameters of AS patients and controls were presented in Table 1. All the sagittal parameters were found to be significantly different in AS patients and controls. Compared with the control group, AS patients had significantly higher PI(47.4° vs. 43.2°, $P<0.001$), PT(38.6° vs. 7.8°, $P<0.001$), TK(53.9° vs. 32.3°, $P<0.001$), TLK(33.3° vs. 6.6°, $P<0.001$), SVA(166.1mm vs. 0.6mm, $P<0.001$), and TPA(47.1° vs. 4.0°, $P<0.001$), whereas AS patients had significantly lower SS(8.8° vs. 35.4°, $P<0.001$), LL(-5.4° vs. -46.3°, $P<0.001$), SPA(120.5° vs. 173.5°, $P<0.001$), and SSA(77.8° vs. 126.9°, $P<0.001$) than those of controls.

The correlations between PI and other spinopelvic sagittal parameters in AS patients and controls were shown in Table 2. For AS patients, PI was found to be significantly positively correlated with TPA($r = 0.533$, $P<0.001$), and negatively correlated with SPA($r = -0.504$, $P<0.001$). However, no correlations were found between PI and SVA, SSA, TK, TLK or LL in AS patients.

Linear regression analysis was also performed to showed that a tendency for positive direct linear association between PI and TPA($R^2 = 0.284$, $P<0.001$), and a tendency for negative direct linear association between PI and SPA($R^2 = 0.254$, $P<0.001$) in AS patients(Table 3, Fig.1).

Discussion

Recently the sagittal morphology of the spine and pelvis has become one of the most focused topics in spinal deformity research. Previous studies have demonstrated that AS patients with kyphosis have significantly different spinopelvic parameters compared with normal controls[12–16]. However correlation between sagittal spinopelvic parameters and the development of spinal disorders in patients with AS is not clearly confirmed yet[7, 13].

In the present study, spinal malalignment in AS patients was also observed. AS patients presented higher PT, TK, TLK, SVA, and TPA, and lower SS, LL, SPA and SSA, which indicated retroversion of the pelvis, more local deformity and greater global imbalance. These results were consistent with previous

published studies[12–14]. We also noticed that in our study the mean value of PI(47.4°) in AS patients with kyphosis was statistically higher than that of controls(43.2°). Debarge et al.[12] found the mean value of PI was 61.9 ° in AS group and 50.6 ° in the control group by analyzing 28 AS patients with fixed kyphosis and 154 asymptomatic volunteers. However, Lee et al.[13, 14] found that AS patients had a lower PI compared to normal controls. The difference might be mainly due to different AS and control population included. A previous study confirmed that Chinese population had lower PI compared with Caucasian individuals[21]. Besides, extremely wide variations have been showed in the value of PI, which ranged from 35° to 85°[22]. Therefore, whether the value of PI was higher or lower in AS still needs more investigations to be confirmed furtherly.

PI, one of the spinopelvic parameters, has the advantage of position-independence and remains unchanged regardless of the motions or postures of the spine or pelvis[5]. It has been reported that PI plays a key role in the regulation of pelvic position and other spinal parameters[3, 22, 23]. Its function and roles in a number of different pathologies of the spine disorders have been reported[5, 6, 8]. Carender et al.[4] founded that low PI was associated with increased proximal junctional kyphosis in early onset scoliosis patients who were treated with growing rods. Cho, et al.[24] demonstrated that higher PI was a risk factor for the development of sagittal imbalance in degenerative lumbar scoliosis after long instrumentation and fusion.

To the best of our knowledge, relatively few studies have addressed the relationship between PI and kyphosis in AS. Debarge et al.[12] proposed that the patients with a high PI would have more kyphotic deformity than those with a low PI if they had the same C7 plumb line position. However, Lee et al.[13] confirmed that AS patients with a lower PI had a greater risk of sagittal imbalance. In their both investigations, only SVA and SSA were analyzed as parameters assessing the whole deformity. So, we wondered what was the real potential role of PI in the pathology of AS with kyphosis. To clarify this question, we evaluated the relationship between PI and the spinopelvic parameters describing local deformity or global sagittal balance in AS patients with thoracolumbar kyphosis.

In our study, the parameters indicating global sagittal balance included TPA, SPA, SVA and SSA. The results showed that in AS patients with thoracolumbar kyphosis increasing value of PI was significantly correlated with more global sagittal imbalance(larger TPA, lower SPA) and there was no association between PI and the local deformity(Fig. 2). However, we also found that PI in AS was not significantly correlated with SVA or SSA, which are also the spinopelvic parameters usually used to measure the whole sagittal deformity. There might be several reasons for this. First, the value of SVA is greatly influenced by pelvic compensation or patients' postures[20, 25]. For this reason, Van Royen et al.[25] suggested that it was not suitable to use SVA to measure the sagittal imbalance in AS from a standing full-length spine radiograph. Second, SSA strongly correlates with SS in a healthy population[17]. Normal individual with higher PI may has higher SSA, which was confirmed by the dates of control group in our study. Third, TPA or SPA is independent of position and pelvic retroversion. TPA also combines the information from both SVA and PT[20]. Besides, SSA or SPA decreases as the deformity increases, while TPA increases as the deformity increases[17, 20]. Therefore, it may be better to use TPA or SPA to evaluate the global sagittal

alignment of spinal deformity. However, the reason why increasing PI was associated with more global sagittal malalignment was not confirmed in this study. We believe that there would be other risk factors of global sagittal malalignment for AS patients with kyphosis, which need more investigations.

There are some limitations in our study that require consideration. First, the present study is essentially a retrospective review. Therefore, a prospective study with a long follow-up may be needed to further confirm the role of PI in the development of deformity of AS. Second, AS patients were examined by X-ray in a natural standing position, however some patients with severe kyphosis might stood with the knees in natural flexion in order to compensate for sagittal imbalance. Thus, some parameters depending on position, such as SVA, were not accurate. Furthermore, the number of normal controls was relatively small and only AS patients with severe kyphosis were included. As such, selection bias may exist in our study. The result in our study should not be generalized to the whole AS population.

Conclusions

This study showed that the spinopelvic sagittal parameters were significantly different in AS patients and controls. Furthermore, the value of PI in AS patients with kyphosis was significantly higher than that of controls. Correlation analysis revealed that increasing PI was significantly correlated with more global sagittal imbalance, not with the local deformity in AS patients with thoracolumbar kyphosis.

Abbreviation List

AS: Ankylosing spondylitis; PI: Pelvic incidence; PT: Pelvic tilt; SS: Sacral slope; TK: Thoracic kyphosis; TLK: Thoracolumbar kyphosis; LL: Lumbar lordosis; SVA: Sagittal vertical axis; C7PL: the C7 plumb line; TPA: T1 pelvic angle; SSA: spinosacral angle; SPA: spinopelvic angle

Declarations

Ethics approval and consent to participate

This study was conducted with approval from the Ethics Committee of Chinese PLA General Hospital. Written informed consent to participate was obtained from all participants.

Consent for publication

We have obtained consent to publish from the participants.

Availability of data and material

The patients' data were collected in the Chinese PLA General Hospital. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

YW designed the study. DS and DQ collected the data. DS, GZ, and TW were involved in the manuscript writing, literature search, data interpretation, and data monitoring. GZ was responsible for the data collection and analysis. All authors read and approved the final manuscript.

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References

- 1.Song K, Zheng G, Zhang Y, Zhang X, Mao K, Wang Y. A new method for calculating the exact angle required for spinal osteotomy. *Spine (Phila Pa 1976)*. 2013;38(10):E616–20.
- 2.Chang KW, Chen YY, Lin CC, Hsu HL, Pai KC. Closing wedge osteotomy versus opening wedge osteotomy in ankylosing spondylitis with thoracolumbar kyphotic deformity. *Spine (Phila Pa 1976)*. 2005;30(14):1584–93.
- 3.Boulay C, Tardieu C, Hecquet J, Benaïm C, Mouilleseaux B, Marty C, 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.
- 4.Carender CN, Morris WZ, Poe-Kochert C, Thompson GH, Son-Hing JP, Liu RW. Low Pelvic Incidence Is Associated With Proximal Junctional Kyphosis in Patients Treated With Growing Rods. *Spine (Phila Pa 1976)*. 2016;41(9):792–7.
- 5.Weinberg DS, Morris WZ, Gebhart JJ, Liu RW. Pelvic incidence: an anatomic investigation of 880 cadaveric specimens. *Eur Spine J*. 2015;25(11):3589–95.
- 6.Hanson DS, Bridwell KH, Rhee JM, Lenke LG. Correlation of pelvic incidence with low- and high-grade isthmic spondylolisthesis. *Spine (Phila Pa 1976)*. 2002;27(18):2026–9.

- 7.Toy JO, Tinley JC, Eubanks JD, Qureshi SA, Ahn NU. Correlation of sacropelvic geometry with disc degeneration in spondylolytic cadaver specimens. *Spine (Phila Pa 1976)*. 2012;37(1):E10–5.
- 8.MD JSB, PhD J-SJM, PhD S-HLM, MD JUK. Radiological analysis of lumbar degenerative kyphosis in relation to pelvic incidence. *The Spine Journal*. 2012;12(11):1045–51.
- 9.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(18):2049–54.
- 10.Le Huec JC, Aunoble S, Philippe L, Nicolas P. Pelvic parameters: origin and significance. *Eur Spine J*. 2011;20 Suppl 5:564–71.
- 11.Liu Z-j, Qian B-P, Qiu Y, Mao S-H, Jiang J, Wang B. Does postoperative PI-LL mismatching affect surgical outcomes in thoracolumbar kyphosis associated with ankylosing spondylitis patients? *Clin Neurol Neurosurg*. 2018;169:71–6.
- 12.Debarge R, Demey G, Roussouly P. Radiological analysis of ankylosing spondylitis patients with severe kyphosis before and after pedicle subtraction osteotomy. *Eur Spine J*. 2009;19(1):65–70.
- 13.Lee JS, Shin JK, Goh TS. Correlation between body image perception and spinopelvic parameters in ankylosing spondylitis. *Br J Neurosurg*. 2018;32(5):469–73.
- 14.Lee JS, Suh KT, Kim JI, Goh TS. Analysis of sagittal balance of ankylosing spondylitis using spinopelvic parameters. *Journal of spinal disorders & techniques*. 2014;27(3):E94–8.
- 15.Qian B-P, Jiang J, Qiu Y, Wang B, Yu Y, Zhu Z-Z. The Presence of a Negative Sacral Slope in Patients with Ankylosing Spondylitis with Severe Thoracolumbar Kyphosis. *The Journal of Bone and Joint Surgery-American Volume*. 2014;96(22):e188–1–6.
- 16.Shin JK, Lee JS, Goh TS, Son SM. Correlation between clinical outcome and spinopelvic parameters in ankylosing spondylitis. *Eur Spine J*. 2013;23(1):242–7.
- 17.Roussouly P, Nnadi C. Sagittal plane deformity: an overview of interpretation and management. *Eur Spine J*. 2010;19(11):1824–36.
- 18.van der Linden S, Valkenburg HA, Cats A. Evaluation of diagnostic criteria for ankylosing spondylitis. A proposal for modification of the New York criteria. *Arthritis Rheum*. 1984;27(4):361–8.
- 19.Wang Y, Zheng GQ, Zhang YG, Song K, Song DY, Zhang XS, et al. Proposal of a New Treatment-Oriented Classification System for Spinal Deformity in Ankylosing Spondylitis. *Spine Deform*. 2018;6(4):366–72.
- 20.Protosaltis T, Schwab F, Bronsard N, Smith JS, Klineberg E, Mundis G, et al. The T1 Pelvic Angle, a Novel Radiographic Measure of Global Sagittal Deformity, Accounts for Both Spinal Inclination and Pelvic

Tilt and Correlates with Health-Related Quality of Life. The Journal of Bone and Joint Surgery-American Volume. 2014;96(19):1631–40.

21.Yong Q, Zhen L, Zezhang Z, Bangping Q, Feng Z, Tao W, et al. Comparison of sagittal spinopelvic alignment in Chinese adolescents with and without idiopathic thoracic scoliosis. Spine (Phila Pa 1976). 2012;37(12):E714–20.

22.Roussouly P, Gollogly S, Berthonnaud E, Dimnet J. 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(3):346–53.

23.Diebo BG, Lafage V, Schwab F. Pelvic Incidence: The Great Biomechanical Effort. Spine (Phila Pa 1976). 2016;41 Suppl 7:S21–2.

24.Cho K-J, Suk S-I, Park S-R, Kim J-H, Kang S-B, Kim H-S, et al. Risk factors of sagittal decompensation after long posterior instrumentation and fusion for degenerative lumbar scoliosis. Spine (Phila Pa 1976). 2010;35(17):1595–601.

25.Van Royen BJ, Toussaint HM, Kingma I, Bot SD, Caspers M, Harlaar J, et al. Accuracy of the sagittal vertical axis in a standing lateral radiograph as a measurement of balance in spinal deformities. Eur Spine J. 1998;7(5):408–12.

Tables

Table 1. Comparison of the spinopelvic parameters between AS patients and normal controls

	AS group(n=94)	Control group(n=30)	P
Sex,M/F	91/3	27/3	0.130
Age(yr)	36.8±9.6	34.4±8.3	0.225
PI (°)	47.4±7.5	43.2±4.6	<0.001*
PT (°)	38.6±11.7	7.8±3.2	<0.001*
SS (°)	8.8±10.2	35.4±3.7	<0.001*
TK (°)	53.9±18.1	32.3±6.2	<0.001*
TLK (°)	33.3±12.7	6.6±5.0	<0.001*
LL (°)	-5.4±14.2	-46.3±6.4	<0.001*
SVA(mm)	166.1±58.1	0.6±15.1	<0.001*
SPA(°)	120.5±15.2	173.5±1.1	<0.001*
SSA(°)	77.8±13.3	126.9±4.1	<0.001*
TPA (°)	47.1±12.5	4.0±1.0	<0.001*

AS, ankylosing spondylitis; M, male; F, Female; PI, Pelvic incidence; PT, Pelvic tilt; SS, Sacral slope; TK, Thoracic kyphosis; TLK, Thoracolumbar kyphosis; LL, Lumbar lordosis; SVA, Sagittal vertical axis; GK, Global kyphosis; SPA, spinopelvic angle; SSA, spinosacral angle; TPA, T1 pelvic angle

*Statistically significant (P<0.05).

Table 2. Correlation coefficient(r) between PI and other sagittal parameters in AS patients and controls

Correlation coefficient(r)	PI			
	AS group	P value	Control group	P value
PT	0.506	<0.001*	0.601	<0.001*
SS	0.159	0.127	0.722	<0.001*
TK	0.171	0.100	0.090	0.637
TLK	-0.67	0.522	-0.292	0.117
LL	-0.135	0.194	-0.540	0.002*
SVA	0.090	0.389	-0.163	0.389
SPA	-0.504	<0.001*	-0.296	0.112
SSA	-0.11	0.919	0.803	<0.001*
TPA	0.533	<0.001*	0.265	0.157

AS, ankylosing spondylitis; PI, Pelvic incidence; PT, Pelvic tilt; SS, Sacral slope; TK, Thoracic kyphosis; TLK, Thoracolumbar kyphosis; LL, Lumbar lordosis; SVA, Sagittal vertical axis; GK, Global kyphosis; SPA, spinopelvic angle; SSA, spinosacral angle; TPA, T1 pelvic angle

*Statistically significant (P<0.05).

Table 3. Linear regression model for PI with TPA and SPA in AS patients

	Unstandardized coefficients	Standardized coefficients	R ² of model	P
TPA	0.323	0.533	0.284	<0.001*
SPA	-0.251	-0.504	0.254	<0.001*

AS, ankylosing spondylitis; PI, Pelvic incidence; SPA, spinopelvic angle; TPA, T1 pelvic angle

*Statistically significant (P<0.05).

Figures

Figure 1

A, Scatter diagram of SPA and PI. B, Scatter diagram of TPA and PI. SPA indicates spinopelvic angle; PI, Pelvic incidence; TPA, T1 pelvic angle.

Figure 2

Lateral X-rays of AS patients showed increasing PI was correlated with more global sagittal imbalance (larger TPA, lower SPA). In Fig.2-A the PI, TPA and SPA were 32.4°, 36.7° and 128.7° respectively. In Fig.2-B the PI, TPA and SPA were 45.9°, 60.4° and 123.3° respectively. In Fig.2-C the PI, TPA and SPA were 56.8°, 66.1° and 99.2° respectively.