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Original Article

Analysis of the spino-pelvic parameters for symptomatic adjacent segment degeneration after posterior lumbar interbody fusion

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Abstract: Purpose: To identify the risk factors of symptomatic adjacent segment degeneration (SASD) after posterior lumbar interbody fusion (PLIF) and to figure out the correlation between spino-pelvic parameters and SASD. Methods: 21 patients who with postoperative SASD during an average follow-up time of 42.14±25.97 months were retrospectively analyzed as the study group. The controlled group consisted of 96 patients who developed no SASD after PLIF. Characteristics of the including patients were investigated in both groups. The spino-pelvic parameters including pelvic incidence (PI), lumbar lordosis (LL), sacral slope (SS), pelvic tilt (PT) were calculated pre- and postoperatively. Univariate and multivariate regression analysis were then performed to identify the related risk factors for SASD after PLIF. Results: The patients in the SASD group showed a significant reduction of postoperative LL (P=0.002) and significant increase of postoperative PT (P=0.005). The postoperative LL (OR=0.911, P=0.004), postoperative PT (OR=1.121, P=0.007) and bone mineral density (BMD) (OR=0.536, P=0.023) were detected to be the most important risk factors for SASD after PLIF while the body mass index (BMI) was selected as a suspicious factor (P=0.068). Conclusion: The risk factors of SASD after PLIF turn out to be multifactorial, the spino-pelvic parameters play an important role in SASD. The BMD, postoperative LL and postoperative PT are inextricably linked with SASD. Our study demonstrates the necessity to restore the PT and maintain the LL in the surgery to reduce the occurrence of SASD.

Keywords: Spino-pelvic parameters, symptomatic adjacent segment degeneration, posterior lumbar interbody fusion

Introduction

Posterior lumbar interbody fusion (PLIF) is an effective surgical treatment for degenerative lumbar diseases [1, 2]. Significant symptom relief and life quality improvement could be achieved after PLIF. However, long-term follow-up reveals the complications like spondylolysis, adjacent segment degeneration or postoperative neurological deficits. The development of degeneration in mobile segment adjacent to the lumbar or lumbosacral spinal fusion unit remains the most common problem after PLIF. Though adjacent segment degeneration (ASD) can be taken as a degenerative progress like normal aging, the cadaveric and the clinic researches implied the acceleration of degenerative change may be related to the adjacent fusion that alters the biomechanics of normal spine [3-5]. In a review by Helgeson MD et al. [6], the ASD rate in lumbar spine after surgery ranged from 0% to 100%. Park's review [7] also demonstrated the incidence for ASD varied from 5.2% to 100% in the long-term follow-up (ranged from 36 to 369 months). Therefore, the measures to prevent such complications are extremely important. The ASD includes the "radiological ASD" and the "symptomatic ASD". However, as is reported, among the large amount of postoperative ASD, only a few of them have clinic symptoms (SASD). Patients with SASD usually need reoperation to fuse the degenerated adjacent segment which reveals the importance of preventing SASD degeneration.

The sagittal spinal balancehas been proved of importance in reconstructive spinal surgery

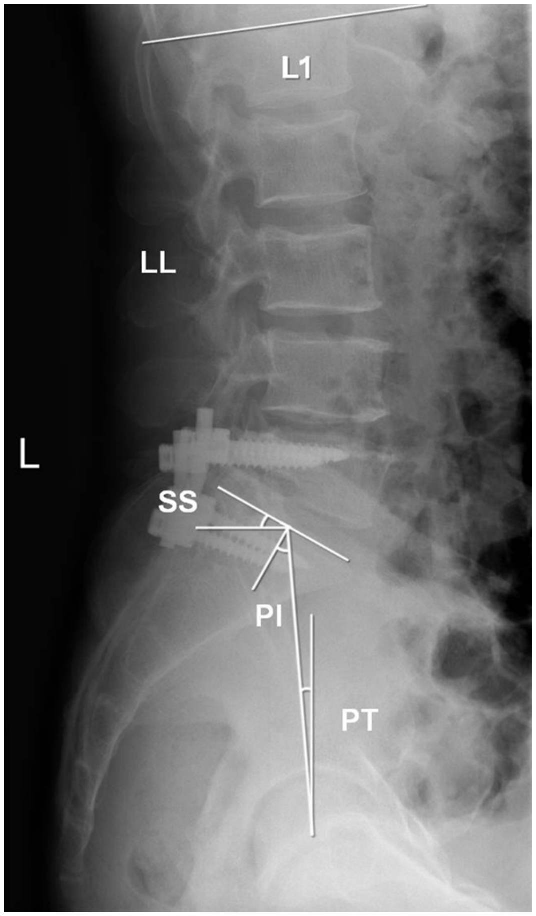

Figure 1. The spino-pelvic parameters (PI, LL, SS and PT) were calculated on standing lateral X-ray images.

in recent years [8]. It is related to the exact description of the relative position of the pelvis and spine, which decides the normal lumbar curvature. Moreover, several studies have showed the importance of maintaining the sagittal balance in clinical treatment [9-11]. Previous literatures focused mainly on the maintaining of sagittal alignment, few of them aimed to figure out the relationship between the spino-pelvic parameters and the complications of PLIF. It is unknown whether the spino-pelvic parameters play an important role in developing SASD during the long term follow-up after PLIF. This study was undertaken to identify the risk factors of SASD after PLIF and to figure out the correlation between spino-pelvic parameters and SASD.

Material and methods

Subjects

We retrospectively analyzed the patients who underwent single level PLIF in our hospital from September 2006 to September 2012. The inclusion criteria were considered as followed: (1) Patients who underwent PLIF with only one segment (L4/L5 or L5/S1) for the degenerative disease; (2) Patients who have complete clinical records and radiographic findings (preoperative magnetic resonance imaging (MRI), standing frontal/lateral X-ray images which include the view of the lumbar vertebrae and the femoral heads); (3) Patients with at least 1 year follow-up.

Radiological evaluation

The preoperative MRI of each patient was reviewed to evaluate the degree of preoperative adjacent disc degeneration using the modified Pfirrmann's classification [12]. Patients with adjacent disc that was classified as Grade VI or more were excluded in this study.

The spino-pelvic parameters were calculated on standing lateral X-rayimages pre- and postoperatively (**Figure 1**).

Pelvic incidence (PI): the angle between a line perpendicular to the upper endplate of the sacrum (S1) and a lineconnecting the middle of the superior endplate of S1 to the middle axis of the femoral heads.

Lumbar lordosis (LL): it is measured by the angle from the superior endplate of the sacrum to the superior endplate of the first lumbar vertebra (L1).

Sacral slope (SS): it is measured as the angle between the horizontal line and the superior endplate of S1.

Pelvic tilt (PT): it is characterized by the angle between a vertical line and the line connecting the middle of the superior sacral plate (S1) and the middle axis of the femoral heads. When the hip axis lies in front of the middle of the sacral plate, it is defined as positive, while negative by contrast [13].

Criteria for SASD

Criteria of ASD: (1) anterior or posterior displacement of >3 mm of the adjacent segment on lateral X-ray images; (2) reduction of intervertebral disc height by 50% of the upper one; (3) a decrease in intervertebral angle of ≥5 on lateral radiograph [14]. The SASD is determined

Table 1. Characteristics of patients in SASD group (Group A) and control group (Group B)

Characteristics	Patients Enrolled		*P* values
	Group A (n=21)	Group B (n=96)	
Gender			0.711
Male	11	46	
Female	10	50	
Age (yr)	56.43±8.79	54.60±12.25	0.522
History of smoking	10	42	0.747
History of alcohol drinking	6	54	0.440
Residence			0.522
Urban	9	34	
Rural	12	62	
BMD (T score)	-1.3±0.93	-0.90±1.17	0.151
BMI (kg/m^2)	25.23±3.52	23.67±3.47	0.068
Symptom duration (month)	5.95±4.84	5.78±5.70	0.960
Fusion level			0.212
L4-5	8	51	
L5-S1	13	45	
Diagnosis			0.409
Lumbar spinal stenosis	11	42	
Lumbar spondylolisthesis	5	23	
Lumbar disc herniation and instability	5	31	
Preoperativeadjacent discmodified Pfirrmann's grade			0.931
Grade 1	0	0	
Grade 2	5	18	
Grade 3	6	30	
Grade 4	6	32	
Grade 5	4	16	
Grade 6	0	0	
Follow-up time (month)	42.14±25.97	40.71±20.23	0.783

as the fusion-related symptoms like lower back pain or radicular symptoms followed by the degeneration of adjacent segment when other causes were excluded.

Patients who developed SASD during follow-up were classified as the study group (Group A). 96 patients who did not develop SASD were selected from the same database from September 2009 to 2010 and were divided into the controlled group (Group B).

All of the patients underwent frontal, lateral, extension and flexionX-ray images of the lumbar spine preoperatively, one week after surgery and at each follow-up time. Preoperative computed tomography (CT) reconstruction of lumbarsegment was also performed to confirm the diagnosis.

Risk factor collection

Patients' Age, gender, history of smoking, history of alcohol drinking, bone mineral density (BMD), body mass index (BMI), symptom duration, fusion level, diagnosis, preoperative adjacent disc modified Pfirrmann's grade, follow-up time, pre- and post-operative spino-pelvic parameters of these two groups were collected.

Statistical analysis

All the data analysis was performedby using SPSS 18.0 for Windows (Chicago, IL, USA). Continuous data were represented as mean± standard deviation. Each continuous variable was analyzed exploratively about its normal distribution using Kolmogorov-Smirnov test. The student t test was used when continuous vari-

Table 2. Spino-pelvic parameters of the patients

Parameters	Patients Enrolled Group A (n=15)	Group B (n=57)	P values
Preoperative data			
Preoperative SS	37.71±9.94	38.45±7.80	0.714
Preoperative PT	15.19±5.56	16.19±5.65	0.468
Preoperative PI	52.90±11.08	54.57±9.80	0.496
Preoperative LL	41.62±8.50	42.75±8.98	0.602
Postoperative data			
Postoperative SS	34.29±7.81	37.06±8.78	0.187
Postoperative PT	20.86±7.47	16.65±5.61	0.005*
Postoperative PI	55.14±9.72	53.71±11.00	0.585
Postoperative LL	35.05±9.37	41.20±7.87	0.002*

*Statistical significance was defined as P<0.05.

ables were compared between the two groups; the Chi-square test was used for the categorical variables. The univariate logistic regression analysis was first performed for each factor. Factors with a value of *P*<0.2 were included in the multivariate analysis. Odd ratios (ORs) for the occurrence of SASD and their 95% confidence intervals (CIs) as an approximation of the relative risk estimates were calculated by multiple logistic regression test and backward selection. *P*-value of less than 0.05 was considered statistical significance.

Results

Group description

The summary of the general information for all patients is presented in **Table 1**. A total of 117 patients were analyzed in this study (57 men, 60 women), of which 21 patients developed SASD during follow-up Considering their primary preoperative diagnosis, 11 suffered from lumbar spinal stenosis, 5 suffered from lumbar disc herniation and 5 had lumbar spondylolisthesis. Another 96 patients did not develop SASD were evaluated as: lumbar spondylolisthesis (n=23), lumbar spinal stenosis (n=42), lumbar disc herniation (n=31). The average age was 56.43±8.79 years for the study group (range from 37 to 76 years) and 54.60±12.25 years for the control group (range from 26 to 84 years). The follow-up time was 42.14±25.97 monthsin the study group and 40.71±20.23 months in the control group respectively. In SASD group, fusion was performed at the L4-5 level in 8 patients and L5-S1 level in 13 patients. No statistically significant differences were detected with respect to patients' age, gender, and history of smoking, history of alcohol drinking, symptom duration and fusion level between the 2 groups. (**Table 1**) The BMI was higher in SASD group (25.23±3.52 kg/m^2) than that in control group (23.67±3.47 kg/m^2), however, it did not present a statistically significant difference between the two groups (P=0.068).

Radiologic evaluation

The pre- and postoperative SS, PT, PI, LL were calculated on standing lateral X-ray image. The details of these parameters were listed in **Table 2**. The patients in the study group showed a significant reduction of postoperative LL (P=0.002) and the increase in the postoperative PT as compared to those in the control group (P=0.005). There were no statistically significant differences of preoperative SS, PT, PI, LL and postoperative SS and PI between the two groups (P>0.05).

Logistic regression analysis

The result of univariate analysis showed that postoperative PT (P=0.007) and postoperative LL (P=0.004) were related to SASD. And patients' BMD (P=0.152), BMI (P=0.071) and postoperative SS (P=0.188) may be the potential risk factors for SASD after PLIF. Therefore these factors as well as the modified Pfirrmann's classification of adjacent disc were selected in the multivariate binary logistic regression model. As a result, the postoperative LL (OR=0.911, P=0.004), postoperative PT (OR=1.121, P=0.007) and BMD (OR=0.536, P=0.023) were detected to be the most important risk factors for SASD. In addition, in the final multivariate model, BMI turned out to be a suspicious factor for SASD (P=0.068) (**Table 3**).

Discussion

In recent years, the spino-pelvic parameters have gained lots of popularity among researches. The growing number of literatures about the spino-pelvic measurements indicate the importance of the parameters in patients undergoing spinal surgeries. In our study, we analyzed the relationship between the spino-pelvic parameters and SASD after PLIF and we demonstrated

Table 3. Outcome of multivariate logistic regression analysis

Variables	B	S.E.	Wald	*P* value	OR (95% CI)
BMD	-0.623	0.275	5.156	0.023*	0.536 (0.313-0.918)
Postoperative PT	0.114	0.043	7.194	0.007*	1.121 (1.031-1.219)
Postoperative LL	-0.094	0.033	8.236	0.004*	0.911 (0.854-0.971)

B=partial regression coefficient; S.E.=standard error; OR=odds ratio; CI=confidence interval. *Statistical significance was defined as P<0.05.

that the BMD, postoperative LL and PT turned out to be the most important risk factors for SASD.

ASD is the most common complication after posterior lumbar interbody fusion. It usually just presents radiological degenerations on follow-up images and SASD is relatively rare. According to the previous literatures, the reason and risk factors for SASD still remains controversial. Some reports indicated that aging, mechanical and biomechanical changes in the fused segment were risk factors [15-18]. Aota et al. believed that elder people were more difficult to adjust to the biomechanical changes after the lumbar fusion, which may be the reason strongly support aging as a main risk factor [19]. But the biomechanical changes of the segments were also widely discussed. Rahm et al. revealed that PLIF increased the loading of the adjacent segments [20]. Nagata et al. [21] found that the increased range of motion was detected in mobile segments adjacent to the fusion segment. Though the risk factors and the mechanism were still unclear, all of the researches implied the fact that the SASD was a multi-factor influenced complication.

Not until recent years have the surgeons started to pay attentions on the spino-pelvic parameters. These researches indicated that the sagittal balance measured by spino-pelvic parameters were of great importance with the SASD: Lazennec JY et al. suggested the sagittal alignment was associated with the SASD after PLIF [22]. In the review performed by Park et al. he concluded several risk factors counting for SASD: age, pre-existing degenerative changes, sagittal malalignment, facet injury, instrumentation and fusion length [7]. Kumar et al. [23] proved the significances of normal sacral inclination and a normal C7 sagittal plumb line for reducing the incidence of SASD.

In the parameters measured on standing lateral X-ray, LL was the most extensively studied. As is reported, the normal range of LL was 30-80° (Cobb method). The abnormality of LL often occurred in the degenerative conditions, which appeared as a loss of LL but leaded to pelvic imbalance and resulting lower back pain [22]. It was in line with our result, we found that the decrease in postoperative LL was in significant correlation with SASD. The reducing in postoperative LL was demonstrated to concentrate the axial load in segmental motion of lumbar spine, which accelerated the procedure of segmentaldegeneration, especially in those segments adjacent to rigid fusion [24, 25].

With the loss of LL, increased PT was also observed in patients with SASD. In other researches, the increased PT, decreased SS anddecreased thoracic kyphosis (TK) canalso exit, that was a chain reaction of the body's compensation for sagittal imbalance [26]. The high PT is the very first and efficient way of compensation.In Berjano's study, the patients who failed after a long thoraco-lumbar fusion surgery were investigated, 78.6% of the patients who needed revision surgery had a PT higher than 20°, and increased postoperative PT waspositively correlated with postoperative clinic symptom [27]. That was thought to be the body's regulation mechanism to compensate for the pelvic imbalance: increased PT and decreased SS for the same PI value [26, 28]. The increased PT with decreased LL result in the "spino-pelvic mismatch", leads to the subsequent dysfunction [13]. Therefore, the reduction of postoperative LL and the increase of postoperative PT were related to the SASD in our study.

Besides PT and LL, our result revealed the lower BMD was one of the important risk factors for SASD. The fact is, the higher BMD contributes to the solid vertebrae and the stabilization of the spine, so when the osteoporosis occurred, the chances of implants loosening increase. That may be the reason why patients with underlying osteoporosis have a higher incidence of ASD. Conventional anti-osteoporotic treatment must be beneficial for patients after PLIF. In Röllinghoff's study, the occurrence of postoperative ASD can reach even 36% in older patients [29]. Older patients may have a lower

T score. However, age of the including patients was not in the final regression model in this study. From the final model, we could find out the *P* value of BMI was 0.068, which indicated that higher BMI should be considered as a suspicious risk factor for SASD. The over-weight patients bear much more load in the lumbar spine. The increasing load in the segment adjacent to fusion segment may accelerate degeneration during long-term follow-up.

There areseveral limitations needto be considered about our results. First of all, as a retrospective study, this research presented only level III evidence. A prospective study is needed to certificate the relation between PT, LL and SASD; Furthermore, the enrolled patients were all heterogeneous, they suffered from several different diseases, and the less homogeneous data was not as convincing as the homogeneous population. Another limitation was that, the result was concluded in a small sample size, which may lead to the false positives. It still needs to be discussed in a large population in the future.

Conclusion

In conclusion, the risk factors for SASD after PLIF turn out to be multifactorial, the spino-pelvic parameters play an important role in SASD. The BMD, postoperative LL and postoperative PT are inextricably linked with SASD. Therefore, it's extremely necessary for the surgeons to restore the PT and maintain the LL in the surgery to reduce the occurrence of SASD.

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Disclosure of conflict of interest

None.

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