S-line as Predictor of Clinical Outcome for Patients Undergone Transforaminal Lumbar Interbody Fusion for Lumbar Spinal Stenosis

Yilin Lu

Second Military Medical University

Jian Zhu

Shanghai Changzheng Hospital

Xi Luo

Shanghai Changzheng Hospital

Kaiqiang Sun

Shanghai Changzheng Hospital

Jingchuan Sun

Shanghai Changzheng Hospital

Jiangang Shi (✉ shijiangangspine@163.com)

Shanghai Changzheng Hospital

Research Article

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Abstract

Background: Some have speculated that LSTV has an impact on lumbar curve. A retrospective study was conducted to evaluate S-line as predictor of clinical outcome for patients undergone transforaminal lumbar interbody fusion for lumbar spinal stenosis.

Methods: 126 patients undergoing transforaminal lumbar interbody fusion were enrolled. S-line stands for the connecting line between the highest points of the iliac crests on both sides. The patients were divided into two groups according to the position of S-line, S-line (-) group included patients whose S-line were between L4 and L5, and S-line (+) group included patients whose S-line is above or below this range, which were divided into two subgroups. Their pre-operative imaging data about sagittal alignment were collected, including lumbar lordosis (LL), sacral slope (SS), pelvic incidence (PI) and pelvic tilt (PT). Clinical outcomes were measured using Japanese Orthopaedic Association (JOA) scores, the Oswestry disability index (ODI), visual analog scale (VAS) before the surgery and postoperatively. The correlation of S-line and clinical outcomes, as well as sagittal alignment and clinical outcomes, were analyzed.

Results: LL, SS, PI, PT and PI minus(-) LL of S-line (-) group were ($45.39^{\circ} \pm 12.68^{\circ}$), ($30.27^{\circ} \pm 10.55^{\circ}$), ($43.32^{\circ} \pm 12.22^{\circ}$), ($13.05^{\circ} \pm 6.52^{\circ}$), ($-2.07^{\circ} \pm 8.20^{\circ}$), respectively, and those parameters of S-line (+) group were (40.29 ± 14.92), ($35.70^{\circ} \pm 14.09^{\circ}$), ($52.59^{\circ} \pm 17.07^{\circ}$), ($16.89^{\circ} \pm 8.24^{\circ}$), ($12.30^{\circ} \pm 9.98^{\circ}$), respectively. Significant difference were seen in the above parameters between S-line (-) and S-line (+) group. For S-line (-) and S-line (+) group, post-operative JOA score were (22.39 ± 2.12), (20.26 ± 2.46), post-operative VAS were (2.07 ± 0.88), (3.14 ± 1.47), the post-operative ODI were (8.36 ± 3.28), (11.82 ± 3.32), the improvement rate is (0.61 ± 0.13), (0.55 ± 0.15), Significant differences of those parameters are seen between S-line (-) group and S-line (+) group.

Conclusion: S-line is a reliable predictor of clinical outcome for patients undergone transforaminal lumbar interbody fusion for lumbar spinal stenosis.

Background

Lumbosacral transitional vertebrae (LSTV) are abnormal conditions commonly occurring in process of spine development. It has been estimated that about 25% of general population suffer from LSTV [1]. The diagnosis of LSTV requires a count of numbers of vertebrae assisted by the imaging of the whole spine from the atlas [25]. But not all patients will choose to do a total spine MR imaging, so X-ray is also an effective diagnostic method. In 1984, Castellvi [16] proposed a classification of LSTV based on X-ray, and it is broadly used till today. However, this method is not perfect. For example, Castellvi's study tended to describe the relationship between LSTV and disc herniation (DH), which made the classification not to adapt to other diseases adequately. And imaging techniques were not advanced enough for the further refinement of this classification. A misdiagnosis rate of about 23% has been reported by Pekindil [2]. Difference of spinopelvic sagittal alignment between lumbar disc herniation and lumbar canal stenosis was studied by Xie et al. in 2018 [27]

Hence, S-line was proposed, devoting to tackling the abovementioned consideration. S-line is the connecting line between the highest points of the iliac crests on both sides, and divided into three types: S-line (-) stands for which are between L4 and L5, S-line (+) I stands for lines above the inferior border of L4, and S-line (+) II stands for those below the superior border of L5. When the S-line shows positive, the patient will be diagnosed with LSTV. (Fig. 1)

The ideal alignment of spine in the sagittal plane is known as sagittal alignment, or sagittal balance, which is resulted from various of organic factors. Sagittal alignment has a significant and measurable impact on spinal diseases [3]. The pervasiveness of malalignment extends through most spinal disorders such as adolescent idiopathic scoliosis, thus the systematic assessment of sagittal plane is used to evaluate the severity of spinal disease [4]. Therefore, there's great significance to maintain a good sagittal alignment or rebuild the it for the patient in time. In recent years, sagittal alignment has gradually been a hot issue. In 2017, Amer et al. described the sagittal alignment of the degenerative human spine [26].

Some have speculated that LSTV has an impact on lumbar curve [9, 16]. The present study is dedicated to analyzing whether S-line is helpful for the decision to reconstruction surgery of sagittal alignment.

Methods

Study design and participants

This was a single center, retrospective study. 126 patients (68 females and 58 males) undergoing transforaminal lumbar interbody fusion (TLIF) in the Second Affiliated Hospital of Naval Medical University from November 2018 to November 2019 were enrolled, which were placed in the standing position for X-ray. Patients were included in the study if: 1. They were diagnosed with lumbar spinal stenosis (LSS) and needed TLIF; 2. The X-ray photographs were complete and clear. Patients were excluded from the study if: 1. They were diagnosed with such vertebral diseases as fracture, tumor, and dislocation; 2. Thoracolumbar transitional vertebrae were obtained. The average age of the patients was 41, with a range from 16 to 79. According to the positions of S-line, patients were divided into two groups: S-line (-) and S-line (+), and S-line (+) patients were divided into two other groups depending on whether they were S-line (+) I or S-line (+) II. This study was approved by the ethics committee of Naval Medical University.

Imaging and clinical outcomes

Imaging outcomes: The imaging data was obtained from imaging department of our institution, including the following parameters: lumbar lordosis (LL, the sagittal Cobb angle measured from the superior end plate of L1 to the sacral end plate), sacral slope (SS, the angle between the horizontal and the sacral end plate), pelvic tilt (PT, the angle composed of a vertical line through the center of the femoral heads and the line from the center of the femoral axis and the midpoint of the sacral end plate), pelvic incidence (PI, the sum of PT and SS) and position of S-line.

Clinical outcomes: The demographic information of the patients was collected, including ages, genders and such comorbidities as hypertension, diabetes, BMI. Clinical outcomes were measured using Japanese Orthopaedic Association (JOA) scores preoperatively and postoperatively.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 25.0 (IBM Armonk, NY, USA). Continuous variables were expressed as mean values $\pm$ standard deviation (SD), and categorical variables were described by proportions (%). The mean values or data distribution of continuous variables were compared by the unpaired 2-tailed Student T test or Mann-Whitney U test. A $P < 0.05$ was considered statistically significant.

Results

Table 1 shows the demographic information of all 126 patients. Among the patients, comparisons of baseline characteristics are set on the basis of the position of the S-line, including sex, age, hypertension, diabetes, BMI. There were no significant between-groups differences in the above indicators.

Table 1
Demographic information of the patients

Variable	group		P value
	S-line (-)	S-line (+)	
Age, mean $\pm$ SD, years	42.01 $\pm$ 16.17	38.58 $\pm$ 12.49	.206
Male, N(%)	40(52.63)	18(36.00)	.067
Comorbidities, N (%)			
Smoke	27(35.52)	15(30.00)	.833
Hypertension	33(43.42)	18(36.00)	.406
Diabetes	13(17.11)	6(12)	.433
Obesity	22(28.95)	13(26.00)	.718

Table 2 shows the comparison of radiographic parameters between S-line (-) and S-line(+) group. LL, SS, PI, PT and PI minus(-) LL of S-line (-) group were ($45.39^{\circ} \pm 12.68^{\circ}$), ($30.27^{\circ} \pm 10.55^{\circ}$), ($43.32^{\circ} \pm 12.22^{\circ}$), ($13.05^{\circ} \pm 6.52^{\circ}$), ($-2.07^{\circ} \pm 8.20^{\circ}$), respectively, and those parameters of S-line(+) group were ($40.29^{\circ} \pm 14.92^{\circ}$), ($35.70^{\circ} \pm 14.09^{\circ}$), ($52.59^{\circ} \pm 17.07^{\circ}$), ($16.89^{\circ} \pm 8.24^{\circ}$), ($12.30^{\circ} \pm 9.98^{\circ}$), respectively. All the above-mentioned parameters were seen significant differences between S-line (-) and S-line(+) patients ($P < 0.05$). Table 3 shows comparison of radiographic parameters between S-line (+) I and II. The results of LL, SS, PI, PT and PI-LL were respectively: S-line (+) I: ($53.73^{\circ} \pm 15.48^{\circ}$), ($47.51^{\circ} \pm 16.66^{\circ}$), ($58.96^{\circ} \pm 21.74^{\circ}$), ($16.08^{\circ} \pm 6.83^{\circ}$), ($9.85^{\circ} \pm 9.04^{\circ}$); S-line (+) II: ($33.36^{\circ} \pm 7.30^{\circ}$), ($29.61^{\circ} \pm 7.27^{\circ}$), ($46.92^{\circ} \pm 13.93^{\circ}$), ($17.31^{\circ} \pm 8.95^{\circ}$), ($13.56^{\circ} \pm 10.34^{\circ}$). The first three parameters were seen significant parameters ($P < 0.05$). (Fig. 2, 3)

Table 2
Comparison of Radiographic Parameters between S-line (-) and S-line(+)

Parameter	S-line (-)	S-line(+)	P-value [#]	R	P-value [*]
LL	45.39 ± 12.68	40.29 ± 14.92	.038	-0.074	.609
SS	30.27 ± 10.55	35.70 ± 14.09	.015	0.069	.634
PI	43.32 ± 12.22	52.59 ± 17.07	.001	0.035	.810
PT	13.05 ± 6.52	16.89 ± 8.24	.004	-0.070	.629
PI-LL	-2.07 ± 8.20	12.30 ± 9.98	.000	0.073	.614
SS-PT	17.23 ± 12.59	18.81 ± 15.55	.532	-0.028	.844
LL-SS	15.12 ± 5.42	4.59 ± 8.64	.000	0.000	.999
SS/PT	4.61 ± 7.71	3.50 ± 5.71	.386	0.038	.769
LL/SS	1.56 ± 0.29	1.18 ± 0.31	.000	0.006	.969
L1-L5 LL	30.92 ± 10.48	32.54 ± 15.38	.483	0.204	.156
L5-S1 LL	15.19 ± 5.90	17.82 ± 8.24	.039	0.066	.649
#: The P-value of T-test.					
*: The P-value of Pearson's correlation.					

Table 3
Comparison of Radiographic Parameters between S-line (+) I and II

Parameter	S-line (+) I	S-line(+) II	P-value [#]	R	P-value [*]
LL	53.73 ± 15.48	33.36 ± 7.30	.000	-0.184	.480
SS	47.51 ± 16.66	29.61 ± 7.27	.000	0.005	.985
PI	58.96 ± 21.74	46.92 ± 13.93	.001	.256	.321
PT	16.08 ± 6.83	17.31 ± 8.95	.620	0.055	.835
PI-LL	9.85 ± 9.04	13.56 ± 10.34	.216	0.075	.782
SS-PT	31.45 ± 18.42	12.29 ± 8.47	.000	0.234	.365
LL-SS	6.22 ± 11.62	3.75 ± 6.67	.342	-0.055	.833
SS/PT	4.66 ± 5.51	2.91 ± 5.80	.308	0.189	.468
LL/SS	1.21 ± 0.35	1.17 ± 0.30	.703	-0.157	.548
L1-L5 LL	46.82 ± 15.68	25.18 ± 8.65	.000	0.294	.252
L5-S1 LL	19.25 ± 11.25	17.08 ± 6.25	.385	0.077	.768
#: The P-value of T-test.					
*: The P-value of Pearson's correlation.					

Tables 4 and 5 shows the JOA scores and improvement rate of patients. For S-line (-), S-line (+), S-line (+) I, S-line (+) II, the Pre-operative JOA score is (12.07 ± 1.91), (12.10 ± 1.67), (12.18 ± 1.51), (12.06 ± 1.77), respectively, the Post-operative JOA score is (22.53 ± 2.46), (20.44 ± 2.52), (20.94 ± 2.46), (20.18 ± 2.56), respectively, the improvement rate is (0.61 ± 0.16), (0.49 ± 0.17), (0.52 ± 0.15), (0.47 ± 0.18), respectively. Significant differences of Post-operative JOA score and improvement rate are seen between S-line (-) group and S-line (+) group. (Fig. 4, 5)

Table 4
JOA scores of all 126 patients

Parameter	S-line (-)	S-line(+)	P-value
Pre-operative JOA score	12.07 ± 1.91	12.10 ± 1.67	.918
JOA score of last follow up	22.53 ± 2.46	20.44 ± 2.52	.000
Pre-operative VAS	6.99 ± 1.37	6.64 ± 1.32	.165
VAS of last follow up	2.07 ± 0.88	3.14 ± 1.47	.000
Pre-operative ODI	40.05 ± 2.97	40.40 ± 3.49	.55
ODI of last follow up	8.36 ± 3.28	11.82 ± 3.32	.000
Improvement rate	0.61 ± 0.16	0.49 ± 0.17	.000

Table 5
JOA scores of S-line(+) patients

Parameter	Type I	Type II	P-value
Pre-operative JOA score	12.18 ± 1.51	12.06 ± 1.77	.819
JOA score of last follow up	20.94 ± 2.46	20.18 ± 2.56	.319
Pre-operative VAS	6.39 ± 1.37	6.35 ± 1.19	.280
VAS of last follow up	3.24 ± 1.35	2.94 ± 1.66	.502
Pre-operative ODI	40.27 ± 3.57	40.65 ± 3.31	.726
ODI of last follow up	12.15 ± 3.52	11.18 ± 2.79	.335
Improvement rate	0.52 ± 0.15	0.47 ± 0.18	.362

Discussion

LSTV is a common segmental abnormality in the process of spinal development, which mainly manifested as the enlargement and widening of the unilateral or bilateral transverse process of L5 and/or S1, and joints or fusions can be formed in severe cases [10]. At least 4% of the population are seen radiographic anomalies in L5 and S1 caused by LSTV [11, 12]. LSTV includes many symptoms, which vary from partial to complete transformation into the other vertebra [13]. Many classifications for LSTV are seen in literature [14, 15], and the most used classification was proposed by Castellvi et al. in 1984 [16]. However, these criteria are not perfect. Limited by imaging technology, fine structures in LSTV could not be seen clearly at that time, leading to the disability to counting the number of vertebrae of patients. Also, Castellvi's classification highlights the relationship between LSTV and DH, and its adaptability to

other diseases have not been seriously demonstrated. LSTV is frequently misdiagnosed for the reasons described above. It has been reported that the rate of misdiagnosis can be as high as 23% [2].

There are many studies on the relationship between LSTV and nearby structures. Paraspinal muscle volume has been found to assist in judging the severity of LSTV [17]. Research findings on pedicles of LSTV patients have shown that LSTV can affect the normal state of the pedicle, and the progression of spondylolysis can also adversely affect patients with LSTV and even exacerbate the degeneration of the intervertebral disc [18, 19]. At present, the best imaging technique for the characterization of LSTV is CT, but the diagnosis is often confirmed by accident for the diagnosis purpose of other diseases [10]. In 2013, Mahato et al. proposed a modified classification criterion according to biomechanics studies [20]. In view of shortcomings of Castellvi's classification, to solve the problem of misdiagnosing and propose a universal imaging method for the diagnosis of LSTV, S-line was proposed based on long-term clinical researches.

Sagittal alignment is a physiological state where muscular forces make the most efficient effort to maintain the normal alignment of the spine and stable standing [21, 22]. Good sagittal alignment provides better biochemical property of spine to keep posture stable and retard the process of disc degeneration [23], and literature has reported sagittal alignment is strongly associated with spinal pathologies such as intervertebral disc degeneration, osteoporosis and low back pain [5]. Lumbar sagittal alignment is defined by several parameters: Lumbar lordosis (LL), Pelvic incidence (PI), pelvic tilt (PT) and sacral slope (SS). Among these, PI refers to the pelvic morphologic angle, which is a fixed parameter unique to each individual and not affected by posture, and $PI = PT + SS$ [6–8]. In recent years, sagittal alignment is a hot topic in research. The impact of sagittal alignment on the pathogenesis of many spinal diseases has been annotated.

According to Table 2, main parameters LL, SS, PI, PT and PI-LL between negative and positive patients are seen statistically significant differences. Among these, PI-LL and PT have been discovered to have definite clinical significance by past researches. It has been demonstrated that LL should match PI within 11° ideally, which means a mismatch greater than 11° is associated with spine degeneration and disability. Meanwhile, a normal PT should be less than 15°, or it will be directly correlated with spinal deformity, leading to pain during walking [5, 24]. In the present study, PI-LL of S-line(-) patients and S-line(+) patients are -2.07° and 12.30° , respectively, and PT are 13.05° , 16.89° , respectively. It is not difficult to find that the two parameters of S-line(+) patients are abnormal, while those of S-line(-) patients are conversely within normal limits.

For the comparison between S-line(+) I and S-line(+) II patients, no significant differences were obtained between them. As for LL, PI and SS, though they are significantly different between type I and type II, they are either in the normal range (a LL between 20° to 70° is considered normal), or not have clear clinical meaning.

In summary, parameters of sagittal alignment are much more normal in S-line(-) group than in S-line(+) group, while significant differences between S-line(+) I and S-line(+) II were not observed.

According to the results in Table 4 and 5, it is not difficult to see that although S-line (-) and (+) patients all obtained good recovery, S-line (-) group achieved a higher improvement rate. Patients whose S-line is between L4 and L5 are more suitable for TLIF.

In the present study, the instructive significance of S-line is explored, which may contribute to the feasibility analyzing of TLIF performed on LSS patients. S-line has several important strengths to be used as an index for the prediction of results of TLIF. First, the triage of patients according to S-line is straightforward and easy to implement. The approximate situation of sagittal alignment of the patients can be confirmed. S-line is strongly associated with prognosis, patients with S-line (-) will receive better prognosis than patients with S-line (+). Also, JOA scores reflect lighter postoperative pains of patients with S-line (-).

In conclusion, compared to S-line (+) patients, S-line (-) patients have better sagittal alignment, and achieve better correction after TLIF. As for S-line (+) patients whose improvement rates are markedly low, whether to perform surgery needs further discussions. S-line is a simple and effective index for LSS patients' decision-making regarding TLIF.

Limitation

This study has several limitations. Firstly, this was a retrospective single-center study, and thus the results need to be prospectively verified by multicenter and randomized-control studies in the future. The reason for the normal PI-LL of patients with S-line (+) has not been fully explained. Thirdly, the sample of patients in this single-center study was relatively small. Further studies with higher level of clinical evidence are warranted to confirm our findings.

Conclusion

This study highlights the clinical significance of S-line to instruct transforaminal lumbar interbody fusion. Patients with S-line(-) have better sagittal alignment and obviously higher improvement rates after TLIF. S-line can be used as an effective and feasible tool for the prediction of surgery outcomes and prognosis.

Abbreviations

LSS: lumbar spinal stenosis

TLIF: transforaminal lumbar interbody fusion

LL: lumbar lordosis

SS: sacral slope

PI: pelvic incidence

PT: pelvic tilt

JOA: Japanese Orthopaedic Association

LSTV: lumbosacral transitional vertebrae

MR: magnetic resonance

DH: disc herniation

BMI: body mass index

SPSS: Statistical Package for the Social Sciences

SD: standard deviation

Declarations

Availability of data and materials

The datasets used and/or analyzed during the current study are not publicly available due to feasibility but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

All procedures performed in studies involving human participants were in

accordance with the ethical standards of the Ethics Committee of Naval Medical University.

Both verbal and written informed consents to participate were obtained from all patients before study conduction. The guarantee was given for confidentiality of their personal information. This study adheres to CONSORT guidelines.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

YL was a major contributor in writing the manuscript; JZ designed the study and performed the examination of the data, and substantively revised the manuscript, XL carried out most of the data analysis. JZ and XL should be considered as co-first authors. KS proposed the idea of study design. JS finished the final assessment of the manuscript. The authors read and approved the final manuscript.

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Figures

Figure 1

Classification of S-line. A. Patients with S-line (-). An S-line is between L4 and L5 is considered negative and thus the patient will be diagnosis free from LSTV; B. Patients with S-line (+) I. S-line (+) I stands for which is above the inferior border of L4. C. Patients with S-line (+) II. S-line (+) II stands for which is below the superior border of L5. The appearance of S-line (+) is considered abnormal, which is the diagnostic basis of LSTV.

Figure 2

Comparison of radiographic parameters between S-line (-) and S-line (+). Statistical differences are seen in most parameters except SS-PT and SS/PT.

Figure 3

Comparison of radiographic parameters between S-line (+) I and II. The results of LL, SS, PI, PT and PI-LL are respectively: S-line (+) I: (53.73°±15.48°), (47.51°±16.66°), (58.96°±21.74°), (16.08°±6.83°), (9.85°±9.04°); S-line (+) II: (33.36°±7.30°), (29.61°±7.27°), (46.92°±13.93°), (17.31°±8.95°), (13.56°±10.34°). LL, SS, PI, SS-PT, L1-L5 LL were statically different between type I and type II.

Figure 4

Comparison of JOA scores between S-line (-) and S-line (+). As a baseline data, preoperative JOA scores have been controlled deliberately. Patients with S-line (-) have better postoperative JOA scores than patients with S-line (+), and the difference is significant.

Figure 5

Improvement rate of the patients. the improvement rate of patients with S-line (-) is 61%, which is significantly higher than the 49% of patients with S-line (+) with P value less than 0.05.