The sagittal spinal profile type: a principal precondition for surgical decision making in patients with lumbar spinal stenosis

*Simon Heinrich Bayerl, MD,¹ Florian Pöhlmann, MD,¹ Tobias Finger, MD,¹ Jörg Franke, MD,² Johannes Woitzik, MD,¹ and Peter Vajkoczy, MD¹

¹Department of Neurosurgery, Charité Universitätsmedizin Berlin; and ²Department of Orthopedic Surgery, Klinikum Magdeburg, Germany

OBJECTIVE Microsurgical decompression (MD) in patients with lumbar spinal stenosis (LSS) shows good clinical results. Nevertheless, 30%–40% of patients do not have a significant benefit after surgery—probably due to different anatomical preconditions. The sagittal profile types (SPTs 1–4) defined by Roussouly based on different spinopelvic parameters have been shown to influence spinal degeneration and surgical results. The aim of this study was to investigate the influence of the SPT on the clinical outcome in patients with LSS who were treated with MD.

METHODS The authors retrospectively investigated 100 patients with LSS who received MD. The patients were subdivided into 4 groups depending on their SPT, which was determined from preoperative lateral spinal radiographs. The authors analyzed pre- and postoperative outcome scales, including the visual analog scale (VAS), walking distance, Oswestry Disability Index, Roland-Morris Disability Questionnaire, Odom's criteria, and the 36-Item Short Form Health Survey score.

RESULTS Patients with SPT 1 showed a significantly worse clinical outcome concerning their postoperative back pain ($VAS_{back-SPT\ 1} = 5.4 \pm 2.8$; $VAS_{back-SPT\ 2} = 2.6 \pm 1.9$; $VAS_{back-SPT\ 3} = 2.9 \pm 2.6$; $VAS_{back-SPT\ 4} = 1.5 \pm 2.5$) and back pain–related disability. Only 43% were satisfied with their surgical results, compared with 70%–80% in the other groups.

CONCLUSIONS A small pelvic incidence with reduced compensation mechanisms, a distinct lordosis in the lower lumbar spine with a high load on dorsal structures, and a long thoracolumbar kyphosis with a high axial load might lead to worse back pain after MD. Therefore, the indication for MD should be provided carefully, fusion can be considered, and other possible reasons for back pain should be thoroughly evaluated and treated.

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LUMBAR spinal canal stenosis is a common disease with a high frequency in the elderly population. The Spine Patient Outcomes Research Trial showed that surgical decompression is superior to conservative treatment with physiotherapy and pain medication only.^{21,22} Decompressive surgery without fusion decreases not only leg pain but significantly reduces back pain as well. Nevertheless, approximately 40% of these patients do not have

a satisfactory relief of symptoms, and more than 20% are not satisfied with surgical treatment. The main cause for these failure rates is unknown, but possible evidence can be found by looking at anatomical preconditions. These patients might have various configurations of the back musculature, differences in degeneration patterns, or differences in static prerequisites concerning spinal alignment or balance. The postoperative sagittal spinal balance

ABBREVIATIONS HRQOL = health-related quality of life; LSS = lumbar spinal stenosis; MD = microsurgical decompression; ODI = Oswestry Disability Index; PI = pelvic incidence; PT = pelvic tilt; RMDQ = Roland-Morris Disability Questionnaire; SF-36 = 36-Item Short Form Health Survey; SFD = sacrum-bicoxofemoral distance; SPT = sagittal profile type; SS = sacral slope; SSA = spinosacral angle; SVA = sagittal vertical axis; VAS, VAS_{back} , VAS_{leg} = visual analog scale, VAS scores of back pain and leg pain; WD = walking distance.

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* Drs. Bayerl and Pöhlmann contributed equally to this work.

has a direct influence on the outcome of patients who received lumbar spinal fusion.^{5,11} However, recently we showed that the sagittal balance does not influence the clinical outcome of patients who suffer from symptomatic lumbar spinal stenosis (LSS) and receive microsurgical decompression (MD) without fusion.⁴ Consequently, the key factor of the high failure rate might be more complex, and it might be connected to other differences of the spinal anatomy.

Previous studies focused on the correlation of postoperative back pain after instrumented surgery and single radiological parameters like the lumbar lordosis or the pelvic tilt (PT).^{10,13} In 2005, Roussouly et al. classified 4 types of lumbar lordosis in the asymptomatic population.¹⁵ Thereafter they investigated the sagittal spinal alignment and pelvic positions in their entirety, and they defined 4 main sagittal profile types (SPTs 1–4) in the asymptomatic population.¹⁶ All SPTs differ concerning their lumbar lordosis and thoracolumbar kyphosis. Furthermore, they present with differences in their pelvic positions. Different lumbar formations and pelvic positions of the SPTs affect the development of degenerative LSS. A substantial influence of the SPTs on the clinical outcome of patients who received a total disc replacement was shown recently.¹⁹ However, a direct relation of the sagittal spinal alignment and the clinical outcome after decompressive microsurgery in the lumbar spine was never investigated.

The aim of our study was to investigate the influence of the SPT on the clinical outcome of patients with LSS who received surgical decompression without fusion, and to correlate sagittal parameters with back pain and disability in these patients.

Methods

Clinical Study and Surgical Procedures

We included 100 patients with symptomatic spinal stenosis who received an MD without fusion. Retrospective data acquisition was authorized by our local ethics committee.

Inclusion criteria were typical symptoms for spinal stenosis, like spinal claudication and back pain, as well as preoperative, full-spine, standing radiographs and the scheduled presentation in our outpatient department pre- and postoperatively for follow-ups. All patients underwent operation for 1- to 3-level LSS between 2011 and 2013 in our department (55 male and 45 female patients). A functional radiograph of the lumbar spine was obtained preoperatively in all cases and did not show anterior sliding of the stenotic segments. A stable spondylolisthesis (Meyerding Grade I) was diagnosed in 34 patients. Exclusion criteria were an indication of instability or severe deformity.

Patients received MD by single-level hemilaminectomy ($n = 13$), single-level laminectomy ($n = 5$), or 1-sided interlaminar fenestration with undercutting ($n = 82$). These are all comparably effective and established techniques to decompress a central spinal stenosis.²⁰

Radiographic Measurements

On preoperative, full-spine, standing lateral radio-

graphs we analyzed pelvic and spinal parameters. Pelvic parameters included the PT, the sacral slope (SS), and the pelvic incidence (PI) (Fig. 1). To analyze the thoracolumbar alignment, we measured the lumbar lordosis and thoracic kyphosis. To investigate the sagittal balance we ascertained the spinosacral angle (SSA) as well as the sagittal vertical axis (SVA; vertical distance between the C-7 plumb line and the posterior edge of the sacrum) and sacrum-bicoxofemoral distance (SFD; distance between the posterior edge of the sacrum and the femoral heads). The ratio of the C7 plumb line and the SFD (C7PL/SFD) was calculated to generate another nonlinear radiographic parameter describing the sagittal balance.^{2,3}

Patient Groups

All patients are assigned to a group according to their SPT.¹⁶ Patients with $SS < 35^\circ$, a high lordosis in the lower lumbar spine, and a long thoracolumbar kyphosis are included in the first group (SPT 1 group) (Fig. 1A). Patients with $SS < 35^\circ$, a long, flat lordosis, and a flat kyphosis are included in the second group (SPT 2 group) (Fig. 1B). The third group (SPT 3 group) contains patients with $35^\circ < SS < 45^\circ$ and proper lumbar lordosis and thoracic kyphosis (Fig. 1C). Patients with $SS > 45^\circ$, strong lordosis, and consecutive high kyphosis were assigned to Group 4 (SPT 4 group) (Fig. 1D). The groupings were performed by 3 independent authors based on long, standing radiographs without further information. In case of disagreement a decision was made by a 2:1 vote. This was the case in only 2 patients.

Clinical Scores

The scores collected from our outpatient department were pre- and postoperative Oswestry Disability Index (ODI), the Roland-Morris Disability Questionnaire (RMDQ), visual analog scale (VAS) scores of leg pain and back pain (VAS_{leg} and VAS_{back}), and the walking distance (WD). Furthermore, we analyzed the postoperative health-related quality of life (HRQOL), which had been assessed by the 36-Item Short Form Health Survey (SF-36).²³ Preoperative SF-36 scores were not available because this score was not set as a standard in our outpatient department in 2011. Odom's criteria were assessed to estimate the patient's satisfaction. Patients who rated their experience "excellent" or "good" were considered as satisfied.

Statistical Methods

GraphPad Prism 5.0c was used for statistical analysis. After analyzing the normal distribution with the Kruskal-Wallis test, either ANOVA or the Mann-Whitney U-test was performed in the 4-group comparison. Student t-test or Mann-Whitney U-test were performed to compare pre- and postoperative scores of each group. Probability values below 0.05 were defined as significant. Further correlation statistics between the single sagittal radiological measurements and the postoperative outcome scores were performed. Pearson and Spearman correlations were conducted.

FIG. 1. Representative images (preoperative long, standing radiographs [upper] and sagittal T2-weighted MR images [lower]) obtained in patients from the 4 groups with different SPTs and LSS. **A:** Patient with SPT 1, who had a small SS (blue lines) and a small PI (red lines). **B:** Patient with SPT 2 and a flat back, who had a small SS and a small PI. **C:** Patient with SPT 3, who had a harmoniously aligned back and medium SS and PI. **D:** Patient with SPT 4, who had strong lumbar lordosis and thoracic kyphosis and a large SS and PI. Figure is available in color online only.

Results

Group Distribution

The SPT 1 group comprised 21, the SPT 2 group had 23, the SPT 3 group had 37, and the SPT 4 group had 19 patients. Compared with findings in demographic studies,¹ the percentages of patients with SPT 4 and SPT 1 in our study were very high. This might be due to increased progress of degeneration in these patients, which possibly caused a degenerative LSS that needed surgical treatment in a higher percentage of patients.³ Groups showed only minimal differences concerning the follow-up time, which

ranged from 6 to 24 months, with a mean follow-up between 14.5 and 17.7 months in the groups. Sex, age, and body mass index did not differ significantly between the groups. The number of surgically treated levels was similar in the groups, and there was no difference concerning perioperative complications or further surgical procedures needed in the groups (Table 1).

Sagittal Parameters

The distribution of patients with spondylolisthesis (Meyerding Grade I) was 6 in the SPT 1 group, 7 in the

TABLE 1. Data in 100 patients with LSS

Variable	SPT 1, n = 21	SPT 2, n = 23	SPT 3, n = 37	SPT 4, n = 19	p Value (btwn groups)
Follow-up (mos)	15.8 ± 6.2	16.4 ± 7.4	17.7 ± 6.0	14.5 ± 5.8	0.313
Age (yrs)	71.7 ± 7.0	69.3 ± 8.5	72.6 ± 8.1	70.8 ± 9.5	0.381
Sex	10 M, 11 F	16 M, 7 F	20 M, 17 F	9 M, 10 F	0.221
BMI (kg/m ²)	28.5 ± 5.7	28.1 ± 7.6	28.0 ± 4.1	26.8 ± 4.1	0.670
Treated levels/patient	1.6 ± 0.6	1.4 ± 0.7	1.6 ± 0.6	1.4 ± 0.5	0.659
No. complications/further spine ops	1/1	1/1	2/1	1/0	0.884

BMI = body mass index.

None of the variables differed significantly between the 4 groups. Values are given as the mean ± SD.

SPT 2 group, 12 in the SPT 3 group, and 9 in the SPT 4 group. In 26 patients a flexion and extension radiograph of the lumbar spine was performed during their follow-up period (5 in the SPT 1 group, 5 in the SPT 2 group, 9 in the SPT 3 group, and 7 in the SPT 4 group). These radiographs did not illustrate any significant instability.

Sacrospinal Configuration

As defined in the SPTs of the Roussouly groups, the cohorts differed concerning SS, and consecutive SPT 1 and SPT 2 groups had a small PI, whereas the SPT 3 group had a medium and the SPT 4 group had a large PI. The PT did not reveal differences among the groups. Corresponding to the SPTs by Roussouly, a high lumbar lordosis could be seen in the SPT 4 group and a physiological flat back in the SPT 2 group. The thoracic kyphosis was decreased in the SPT 2 group as well (Table 2).

Global Sagittal Balance

The sagittal balance did not show significant differences between the groups. The SSA was larger in SPT 3 and SPT 4 because of the pelvic position and the horizontal position of the sacral plate in SPT 1 and SPT 2. We observed a diminished SSA compared with the general population, which might be due to a late stage of

the lumbar degeneration process in particular. If only the linear parameter SVA is considered, the impression of a slightly enhanced imbalance in the SPT 1 and SPT 2 group was conveyed. But when the position of the pelvis is taken into account and the SVA in relation to the sacrofemoral distance is considered, the groups had the same preoperative conditions of global sagittal balance (Table 2).^{2,3}

Clinical Parameters

All groups had very similar preoperative clinical baseline parameters. Preoperative back pain parameters and disability scores with VAS_{back}, the ODI, and the RMDQ did not present significant differences, and also VAS_{leg} and the preoperative WD were nearly equal among the groups. All parameters demonstrated a serious health-related limitation in daily life.

Microsurgical decompression led to a significant reduction of leg pain and consecutively to an improvement of the WD in all groups to a similar degree (Table 3). However, in contrast to the other cohorts, the SPT 1 group did not demonstrate a satisfactory reduction of back pain, and the postoperative improvements in the ODI score and the RMDQ results were not significant either. The postoperative results of these 3 scores (with focus on back

TABLE 2. Radiological parameters in 100 patients with LSS

Parameter	SPT 1, n = 21	SPT 2, n = 23	SPT 3, n = 37	SPT 4, n = 19	p Value (btwn groups)
Sagittal spine curve					
LL (°)	32.8 ± 12.5	21.5 ± 10.1	40.0 ± 10.2†††	54.2 ± 13.5***†††††	<0.0001
TK (°)	47.5 ± 11.1	37.1 ± 11.0*	44.3 ± 12.4	50.3 ± 14.1†	0.0137
Pelvic					
PI (°)	48.1 ± 9.4	47.1 ± 9.8	58.8 ± 9.2	70.6 ± 9.7***†††	<0.0001
SS (°)	25.0 ± 9.6	24.5 ± 4.9	37.4 ± 3.0***†††	49.2 ± 5.3***†††††	<0.0001
PT (°)	21.9 ± 5.6	22.6 ± 7.1	21.5 ± 8.7	21.8 ± 10.6	0.967
Balance					
SSA (°)	109.4 ± 13.4	107.4 ± 8.6	121.4 ± 6.9**†††	133.8 ± 9.2***††††	<0.0001
SVA (mm)	61.2 ± 48.7	74.3 ± 47.1	55.1 ± 33.2	52.7 ± 42.2	0.18
C7/SFD	1.1 ± 0.9	1.2 ± 0.7	1.1 ± 0.8	1.2 ± 1.9	0.949

C7/SFD = ratio between SVA and vertical bicoxofemoral axis; curve = curvature; LL = lumbar lordosis; TK = thoracic kyphosis.

The SPT was determined from preoperative radiographs. Values are given as the mean ± SD. Significant difference compared to SPT 1: *p < 0.05; **p < 0.01; and ***p < 0.001. Significant difference compared to SPT 2: †p < 0.05; ††p < 0.01; and †††p < 0.001. Significant difference compared to SPT 3: ‡p < 0.05; ‡‡p < 0.01; and ‡‡‡p < 0.001.

TABLE 3. Clinical parameters in 100 patients with LSS

Parameter	SPT 1, n = 21	SPT 2, n = 23	SPT 3, n = 37	SPT 4, n = 19	p Value (btwn groups)
Back pain					
VAS _{back} preop	6.6 ± 3.0	7.0 ± 2.5	7.1 ± 2.5	6.3 ± 3.2	0.879
VAS _{back} postop	5.4 ± 2.8	2.6 ± 1.9*	2.9 ± 2.6*	1.5 ± 2.5***	0.0002
p value (pre- vs postop)	0.057	<0.0001	<0.0001	0.0001	
Δ VAS _{back}	-1.8 ± 2.2	-3.1 ± 4.0	-4.0 ± 3.1	-4.7 ± 3.7*	0.0347
ODI preop	47.8 ± 11.8	50.4 ± 16.4	50.2 ± 16.5	53.7 ± 17.4	0.708
ODI postop	41.0 ± 13.4	26.7 ± 19.4*	26.3 ± 16.6*	19.8 ± 19.4**	0.015
p value (pre- vs postop)	0.086	<0.0001	<0.0001	<0.0001	
Δ ODI	-8.7 ± 16.0	-23.6 ± 16.9	-23.5 ± 22.0*	-33.8 ± 28.0**	0.053
RMDQ preop	13.5 ± 5.5	14.7 ± 6.2	11.8 ± 6.0	15.5 ± 5.8	0.136
RMDQ postop	12.9 ± 4.8	7.8 ± 5.8*	8.6 ± 5.7*	4.9 ± 5.6***	0.0003
p value (pre- vs postop)	0.560	0.0004	0.0185	<0.0001	
Δ RMDQ	-0.7 ± 6.0	-7.0 ± 6.8	-3.2 ± 7.0	-10.6 ± 9.5**	0.002
Leg pain					
VAS _{leg} preop	5.6 ± 2.5	6.7 ± 2.1	6.3 ± 3.4	5.7 ± 2.9	0.208
VAS _{leg} postop	3.6 ± 2.4	2.9 ± 2.8	2.9 ± 2.9	2.5 ± 2.9	0.605
p value (pre- vs postop)	0.0035	<0.0001	<0.0001	0.0027	
Δ VAS _{leg}	-2.0 ± 3.1	-3.8 ± 3.6	-3.4 ± 3.8	-3.3 ± 3.2	0.344
WD preop (m)	431 ± 1066	500 ± 709	387 ± 615	253 ± 319	0.922
WD postop (m)	1001 ± 1523	1644 ± 1990	1800 ± 2104	1907 ± 2094	0.369
p value (pre- vs postop)	0.047	0.0466	<0.0001	0.0044	
Δ WD (m)	569 ± 1227	1097 ± 1662	1413 ± 2129	1654 ± 2102	0.141
Odom's criteria	Satisfied: 42.9% Excellent: 3 Good: 6 Fair: 5 Poor: 7	Satisfied: 69.6% Excellent: 12 Good: 4 Fair: 2 Poor: 5	Satisfied: 81.1% Excellent: 20 Good: 10 Fair: 3 Poor: 4	Satisfied: 73.7% Excellent: 9 Good: 5 Fair: 0 Poor: 5	
SF-36 PCS	34.1 ± 10.1	38.1 ± 11.3	36.1 ± 9.5	40.1 ± 10.3	0.2711
SF-36 MCS	39.9 ± 15.7	42.3 ± 15.5	40.6 ± 15.8	43.2 ± 10.9	0.8811

MCS = Mental Component Score; PCS = Physical Component Score.

Back pain parameters: VAS_{back}, ODI, and RMDQ scores in the SPT 1 group were significantly increased compared to other groups. Leg pain parameters: VAS_{leg} was reduced by decompressive surgery in all groups, and thereby the WD improved. All clinical parameters were measured pre- and postoperatively, and their change (Δ) after surgery was calculated. Patient satisfaction as measured by Odom's criteria (those giving ratings of "good" and "excellent" are considered satisfied patients) was significantly reduced in the SPT 1 group. Postoperative HRQOL was measured by the Physical and Mental Component Scores of SF-36, and showed reduced HRQOL in the SPT 1 group, which is not statistically significant. Significant difference compared to SPT 1: *p < 0.05; **p < 0.01; and ***p < 0.001.

pain and pain-related disability) were rated more negatively in the SPT 1 group in comparison with the other groups.

Therefore, the satisfaction of patients with the surgical procedure was significantly lower, as we could demonstrate with Odom's criteria. Only 43% of the patients with SPT 1 were satisfied with the result of the operative procedure (rating it "good" or "excellent"), whereas 70%–81% of all other patients were rated as satisfied. The HRQOL was lower in the SPT 1 group, but the difference was not statistically significant (Table 3).

Correlation analysis only showed a slightly significant negative correlation between the SS and postoperative VAS_{back} and ODI, with a Pearson's r value of -0.37 and -0.24, respectively. Statistical analysis did not show a significant correlation between the follow-up time point and back pain scores (Pearson's r value of 0.137 [p = 0.173] for follow-up and postoperative VAS_{back}).

Discussion

Our study found that the characteristic types of sagittal spinal alignment with their anatomical preconditions have a significant influence on the outcome of symptomatic spinal stenosis after MD. The SPT 1 group features a retroverted pelvis with a small SS and a generally small PI. It contains a strong lordosis in the lower lumbar spine and a long thoracolumbar kyphosis, which results in a high load on the dorsal musculoskeletal structures of the lower back and a high axial load on the intervertebral discs in the thoracolumbar junction (Fig. 2A). This might increase the probability of disc degeneration in the kyphosis area and an increased load on facet joints in the high lordotic lower segments. An MD of the spinal stenosis performed using a dorsal approach is followed by increased postoperative back pain. This might be due to a high load on the facet joints, ligaments, and back musculature. Furthermore, a

FIG. 2. Four different SPTs (1–4) with differences in their thoracolumbar alignment and pelvic position. **A:** The SPT 1 group, with a strong lordosis in the lower lumbar spine but a small general lumbar lordosis and a long thoracolumbar kyphosis. This results in a high disc load at the thoracolumbar junction and a high load on the dorsal musculoskeletal structures and facet joints of the lower lumbar spine. **B:** The SPT 2 group has the smallest lumbar lordosis and thoracic kyphosis. This results in a high axial load on the intervertebral discs. **C:** The SPT 3 group, which has a harmonious thoracolumbar alignment and a medium SS and PI. **D:** The SPT 4 group, with a large PI, high lumbar lordosis, and a high thoracic kyphosis. The result is high translational force and a higher risk of spondylolisthesis. Figure is available in color online only.

small SS and a small PI in SPT 1 result in a limited possibility of compensation mechanisms. Patients with SPT 1 show an improvement in leg pain and claudication symptoms after surgical decompression, but the back pain and the back pain–related disability scores do not indicate a postoperative benefit. Less than 50% of patients are satisfied with their surgical results.

In contrast, all other SPTs demonstrate a very good postoperative outcome. Leg pain and back pain scores improve significantly after surgical decompression. Even the postoperative HRQOL score was worse in the SPT 1 group, but the results were not significant compared with the other groups. A higher number of patients would be helpful to illustrate the difference in terms of QOL. Between 70% and 80% are satisfied with their benefit after surgery, possibly due to very different loading patterns of the lumbar spine in these patients: the SPT 2 group has a very flat back with a retroverted pelvis and a narrow PI accompanied by a high axial disc pressure (Fig. 2B); Type 3 is the most harmoniously aligned SPT, with a medium SS, a medium PI, and a proper thoracolumbar curvature (Fig. 2C); and the SPT 4, with a distinct lordosis and large kyphosis, is more likely to develop a lysis (Fig. 2D).

Despite the SPT 1 being a critical reason for patients with degenerative spine disease to experience back pain, our data show that these patients do not have higher back pain scores before surgical decompression compared with

the SPT 2–4 groups. The differences concerning back pain–related disability can only be seen after surgical decompression. The surgical procedure—with its dorsal approach and muscular as well as bony preparation—might increase the back pain in patients with SPT 1 who have a high load on dorsal musculature and facet joints, particularly after surgery. Furthermore, we know that LSS leads to severe leg and back pain, and that decompression is followed by relief of both.^{7,24} Additional back pain caused by spinal degeneration and SPT 1 alignment should not consequently lead to a higher VAS score in these patients before surgical decompression, because the back pain related to the LSS is more dominant.

To investigate the influence of single sagittal parameters on the clinical outcome of the patients after decompression without fusion, we performed correlation statistics. We analyzed whether pelvic parameters or sagittal parameters of the thoracolumbar spine correlate with outcome scores. Surprisingly, a low lumbar lordosis does not show a significant correlation with postoperative back pain or disability. Only a weak negative correlation could be seen between the SS and the postoperative VAS_{back} and ODI scores. Hence, patients with spinal stenosis and a pronounced retroverted pelvis have the tendency to suffer from increased back pain after decompressive surgery. However, the Pearson's *r* value was only -0.37 and -0.24 for VAS_{back} and ODI scores, respectively. According to that calculation, the position of the pelvis or the lumbar lordosis are not the cardinal reasons for a bad outcome with severe back pain after MD. These results represent a major difference compared with clinical postfusion studies that clearly demonstrate a worse outcome in patients with an iatrogenically fixed flat back, including a decreased lumbar lordosis, a small SS, and a consecutive sagittal imbalance.¹⁷ This disparity demonstrates that postfusion studies cannot be transferred to a nonfusion model. Caution should be exercised before we accept that patients with spinal stenosis and a flat lumbar lordosis need a sagittal correction to the same extent as patients with iatrogenically fixed flat backs.

Lafage et al. correlated the spinopelvic parameters of patients with adult spinal deformities, who did not receive a surgical correction, with HRQOL scores. They found a moderate negative correlation between the spinopelvic inclination and the HRQOL.¹² Furthermore, Schwab et al. could demonstrate a correlation between a low lumbar lordosis and a decreased QOL.¹⁸ However, those authors concentrated on patients with secondary, severe spinal deformity. We identified these parameters to be not as critical in patients with degenerative spine disease and without severe deformities.

Studies that investigated sagittal parameters in asymptomatic patients and in patients with low-back pain found a correlation between a low SS, a flat lumbar lordosis, and low-back pain.^{6,9} Surgeons who are experienced in deformity surgery could argue that patients with an extended hip and a low lumbar lordosis should be considered for instrumentation if surgical decompression is needed. However, our study clearly differentiates between more detailed anatomical preconditions in patients with low SS and low lumbar lordosis. In fact we turn our attention to the whole complex of the lumbar sagittal alignment. Surprisingly,

the group with the lowest lumbar lordosis plus small SS (the SPT 2 group) displays a very good clinical outcome after surgery. These results clarify that the lumbar lordosis and the pelvic position cannot be taken individually as a major parameter for surgical decision making. Interesting enough was the overall distribution of patients to the Roussouly Types 1–4, which was materially different from what we know for a healthy population.¹ Whether this reflects the possibility that patients from the SPT 3 group (because their percentage within the healthy population is much higher) are at a generally lower risk of needing a decompression for stenosis, or the possibility that there could be a change in the distribution of Roussouly types among those patients with degeneration and an indication for an operative decompression, is a wide-open question. For further studies this should be taken into consideration, with the goal of better indicating operative solutions for those patients.¹⁴

Conclusions

The main configuration related to a poor outcome with regard to back pain is the combination of a narrow SS and a low total lumbar lordosis, but a high lordosis in the lower lumbar spine—sometimes only distributed over 1 segment. Patients with these anatomical preconditions and an LSS without instability or severe deformity can be considered for MD without instrumentation. Nevertheless, they should be informed about their high risk of postoperatively lingering back pain. The main limitations of our study are the retrospective data acquisition and the lack of postoperative radiographic controls. Further studies with follow-up radiographs are required to find out whether a change of SPT can be achieved via decompression without fusion, as it was shown for the global sagittal balance.⁸ Moreover, it should be investigated whether an additional instrumentation can offer an improvement in back pain-related disability and possibly result in a higher patient satisfaction in individuals with SPT 1. Finally, as a first step we should evaluate more diligently the reasons for back pain in these patients, and differentiate between muscular pain, facet pain, and discogenic back pain, to optimize the conservative and surgical treatment.

References

1. Araújo F, Lucas R, Alegrete N, Azevedo A, Barros H: Individual and contextual characteristics as determinants of sagittal standing posture: a population-based study of adults. *Spine (Phila Pa 1976)* **J 14**:2373–2383, 2014
2. Barrey C, Roussouly P, Le Huec JC, D'Acunzi G, Perrin G: Compensatory mechanisms contributing to keep the sagittal balance of the spine. *Eur Spine J* **22 (Suppl 6)**:S834–S841, 2013
3. Barrey C, Roussouly P, Perrin G, Le Huec JC: Sagittal balance disorders in severe degenerative spine. Can we identify the compensatory mechanisms? *Eur Spine J* **20 (Suppl 5)**:626–633, 2011
4. Bayerl SH, Pöhlmann F, Finger T, Onken J, Franke J, Czabanka M, et al: The sagittal balance does not influence the one year clinical outcome of patients with lumbar spinal stenosis without obvious instability after microsurgical decompression. *Spine (Phila Pa 1976)* **40**:1014–1021, 2015
5. Bourghli A, Aunoble S, Reebye O, Le Huec JC: Correlation of clinical outcome and spinopelvic sagittal alignment after surgical treatment of low-grade isthmic spondylolisthesis. *Eur Spine J* **20 (Suppl 5)**:663–668, 2011
6. Chaléat-Valayer E, Mac-Thiong JM, Paquet J, Berthonnaud E, Siani F, Roussouly P: Sagittal spino-pelvic alignment in chronic low back pain. *Eur Spine J* **20 (Suppl 5)**:634–640, 2011
7. Försth P, Ólafsson G, Carlsson T, Frost A, Borgström F, Fritzell P, et al: A randomized, controlled trial of fusion surgery for lumbar spinal stenosis. *N Engl J Med* **374**:1413–1423, 2016
8. Fujii K, Kawamura N, Ikegami M, Niitsuma G, Kunogi J: Radiological improvements in global sagittal alignment after lumbar decompression without fusion. *Spine (Phila Pa 1976)* **40**:703–709, 2015
9. 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)* **19**:1611–1618, 1994
10. Kawakami M, Tamaki T, Ando M, Yamada H, Hashizume H, Yoshida M: Lumbar sagittal balance influences the clinical outcome after decompression and posterolateral spinal fusion for degenerative lumbar spondylolisthesis. *Spine (Phila Pa 1976)* **27**:59–64, 2002
11. Korovessis P, Repantis T, Papazisis Z, Iliopoulos P: Effect of sagittal spinal balance, levels of posterior instrumentation, and length of follow-up on low back pain in patients undergoing posterior decompression and instrumented fusion for degenerative lumbar spine disease: a multifactorial analysis. *Spine (Phila Pa 1976)* **35**:898–905, 2010
12. Lafage V, Schwab F, Patel A, Hawkinson N, Farcy JP: Pelvic tilt and truncal inclination: two key radiographic parameters in the setting of adults with spinal deformity. *Spine (Phila Pa 1976)* **34**:E599–E606, 2009
13. Lazennec JY, Ramaré S, Arafati N, Laudet CG, Gorin M, Roger B, et al: Sagittal alignment in lumbosacral fusion: relations between radiological parameters and pain. *Eur Spine J* **9**:47–55, 2000
14. Pereira P, Buzek D, Franke J, Senker W, Kosmala A, Hubbe U, et al: Surgical data and early postoperative outcomes after minimally invasive lumbar interbody fusion: results of a prospective, multicenter, observational data-monitored study. *PLoS One* **10**:e0122312, 2015
15. 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)* **30**:346–353, 2005
16. Roussouly P, Pinheiro-Franco JL: Biomechanical analysis of the spino-pelvic organization and adaptation in pathology. *Eur Spine J* **20 (Suppl 5)**:609–618, 2011
17. Savage JW, Patel AA: Fixed sagittal plane imbalance. *Global Spine J* **4**:287–296, 2014
18. Schwab F, Dubey A, Pagala M, Gamez L, Farcy JP: Adult scoliosis: a health assessment analysis by SF-36. *Spine (Phila Pa 1976)* **28**:602–606, 2003
19. Strube P, Hoff EK, Perka CF, Gross C, Putzier M: Influence of the type of the sagittal profile on clinical results of lumbar total disc replacement after a mean follow-up of 39 months. *Clin Spine Surg* **29**:291–299, 2016
20. Thomé C, Zevgaridis D, Leheta O, Bänzner H, Pöckler-Schöniger C, Wöhrle J, et al: Outcome after less-invasive decompression of lumbar spinal stenosis: a randomized comparison of unilateral laminotomy, bilateral laminotomy, and laminectomy. *J Neurosurg Spine* **3**:129–141, 2005
21. Weinstein JN, Tosteson TD, Lurie JD, Tosteson A, Blood E, Herkowitz H, et al: Surgical versus nonoperative treatment for lumbar spinal stenosis four-year results of the Spine Patient Outcomes Research Trial. *Spine (Phila Pa 1976)* **35**:1329–1338, 2010

22. Weinstein JN, Tosteson TD, Lurie JD, Tosteson AN, Blood E, Hanscom B, et al: Surgical versus nonsurgical therapy for lumbar spinal stenosis. **N Engl J Med** **358**:794–810, 2008
23. Zanolli G, Jönsson B, Strömqvist B: SF-36 scores in degenerative lumbar spine disorders: analysis of prospective data from 451 patients. **Acta Orthop** **77**:298–306, 2006
24. Zweig T, Enke J, Mannion AF, Sobottke R, Melloh M, Freeman BJC, et al: Is the duration of pre-operative conservative treatment associated with the clinical outcome following surgical decompression for lumbar spinal stenosis? A study based on the Spine Tango Registry. **Eur Spine J** **26**:488–500, 2017

Disclosures

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Author Contributions

Conception and design: Vajkoczy, Franke, Woitzik. Acquisition of data: Pöhlmann. Analysis and interpretation of data: Bayerl, Pöhlmann, Finger. Drafting the article: Bayerl. Critically revising the article: Vajkoczy, Finger, Franke, Woitzik. Reviewed submitted version of manuscript: Vajkoczy, Franke, Woitzik. Statistical analysis: Bayerl, Finger. Study supervision: Vajkoczy.

Correspondence

Peter Vajkoczy, Department of Neurosurgery, Charité Universitätsmedizin Berlin, Augustenburger Platz 1, Berlin 13353, Germany. email: peter.vajkoczy@charite.de.