Original Article

The change of Roussouly classification after posterior lumbar fusion surgery

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Background: Roussouly classification is an important morphologic classification which can help to determine high local stress zones of the spine. Different lumbar morphologies of Roussouly type suggest different biomechanics leading to degenerative evolution. This study aimed both to describe the change of the Roussouly classification of the human spine after posterior lumbar fusion surgery and to explore the influencing factors of postoperative Roussouly type.

Methods: The study is a retrospective case-control study on preoperative and postoperative Roussouly types. A total of 167 patients with lumbar degenerative disease who had undergone short-level transforaminal lumbar interbody fusion surgery between January 2014 and December 2017 in the Department of Orthopedic Surgery, First Affiliated Hospital, Air Force Medical University, were recruited. Preoperative and postoperative general data including gender, age, follow-up time, Oswestry disability index (ODI) score, visual analogue scale (VAS) score, diagnosis, and surgical segment were recorded. Clinical parameters including pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL), thoracic kyphosis (TK), and sagittal vertical axis (SVA) were measured using Surgimap software, and the Roussouly classification was assessed.

Results: This study included 86 male patients and 81 female patients with a mean age of 52.0±12.4 [14–88] years. The mean follow-up time for these patients was 11.5±6.9 months. The value of sagittal alignment parameters changed after the posterior lumbar fusion surgery, except for the PI value (P=0.591). Roussouly classification changed after surgery. The preoperative Roussouly values of preoperative PI, SS, and LL were significantly different in patients of 4 postoperative Roussouly types.

Conclusions: The Roussouly classification changes after posterior lumbar fusion surgery. This change is independent of gender, age, follow-up time, and the number of surgical segments. The preoperative Roussouly type and PI value are essential in predicting one's postoperative Roussouly type.

Keywords: X-ray; lumbar spine; Roussouly classification; sagittal alignment; posterior lumbar fusion surgery

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Introduction

The importance of sagittal balance has become increasingly recognized and studied by researchers over the past decade (1), and numerous studies investigating the sagittal balance in humans have been conducted (2-8). Due to the complicated nature of the parameters set by surgeons to measure sagittal curvature, Pierre Roussouly *et al.* proposed a comprehensive classification system of variations in the sagittal morphology of the spine that includes a description of the orientation of the pelvis (9). The Roussouly classification is based on the value of SS and the position of the lumbar lordosis apex. Previous studies have examined the relationship between the classification and clinical outcomes (10-13). This morphologic classification can help to determine high local stress zones of the spine (14), and different Roussouly type lumbar morphologies indicate different biomechanics leading to degenerative evolution (15).

Fusion surgery from the posterior approach is an important and effective method for suitable patients with lumbar degenerative disease to stabilize target segments, decompress neural elements, and restore spinopelvic curvature (16). The process of surgery may change some sagittal alignment parameters, but no current studies have described the influence of lumbar spine surgery on a patient's Roussouly type, and thus individualized rehabilitation plans lack a theoretical basis. This study represents a preliminary exploration of the changing tendency and influential factors of Roussouly types after short-level transforaminal lumbar interbody fusion surgery, which would offer potential guidance in predicting general degenerative evolution tendency and proposing corresponding rehabilitation advice to patients according to their preoperative sagittal alignment features. We present the following article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-22-365/rc).

Methods

Patients

In this case-control study, patients whose surgeries were conducted by uniformly trained doctors between January 2014 and December 2017 were retrospectively recruited. The cases had all been operated on in the orthopedic department, with a minimum follow-up of 6 months. The inclusion criteria were as follows: (I) patients who had lumbar degenerative disease (lumbar disc herniation, lumbar spinal stenosis, and degenerative lumbar spondylolisthesis) and had undergone short-level transforaminal lumbar interbody fusion surgery (fusion level ≤3), (II) preoperative and postoperative lateral full-length radiographs of the spine, and (III) a minimum 6-month follow-up. The exclusion criteria were as follows: (I) no previous lumbar spine surgery; (II) lumbar intraspinal canal tumor; (III) lumbar vertebra fracture or fracture nonunion; (IV) severe lower limb joint disease, pelvic lesion, or spine deformity; (V) lumbar infectious diseases or having been subjected to a second lumbar surgery; (VI) lumbar spondylolysis or spondylolisthesis greater than grade 2; and (VII) central or peripheral nervous system disease. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional review board of the First Affiliated Hospital, Air Force Medical University, and individual consent for this retrospective analysis was waived.

Surgical procedure

The patient was placed in a prone position following general anesthesia. A posterior midline incision was made, and the posterior bone elements of the spine were exposed to the bases of the transverse processes. Pedicle screws were then inserted into the pedicles of the target level, after which C-arm X-ray was used to ensure that the screws were well settled. Lamina was removed in the range of below one-half of the upper vertebral plate and above one-third of the lower vertebral plate. The spinal canal was entered through the radiculopathy side or the side with more severe symptoms. Discectomy was performed through this unilateral posterolateral transforaminal approach. After the discectomy, the endplate was curetted to the bleeding bone. The graft bone was prepared by removing cartilage and fibrous tissue from the local excised bone. The allograft bone was used when the amount of autogenous bone was insufficient. Bone fragments were placed in an interbody cage, which was positioned at an oblique orientation in the intervertebral space after the residual prepared bone fragments had filled the space. The nerve root was checked and confirmed to be well decompressed, and the rod–screw system was tightened and cross-linked before the wound was closed, with a drain tube being left in.

Imaging analysis

Each patient was asked to undergo standing full-length

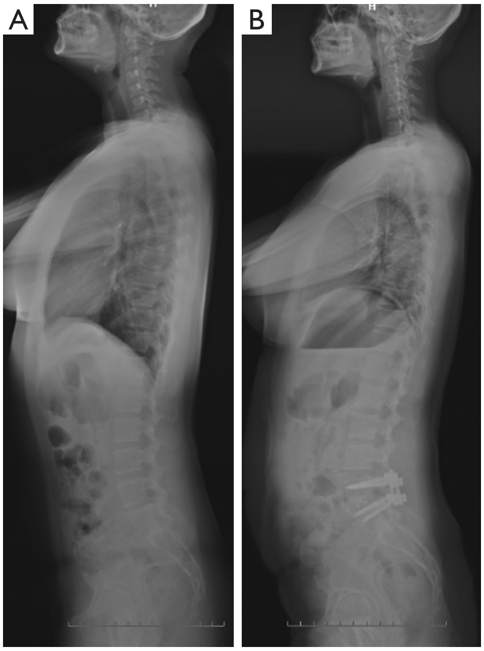

Figure 1 Standing full-length spine lateral X-ray radiograph. (A) X-ray before the surgery. (B) X-ray 12 months after the surgery.

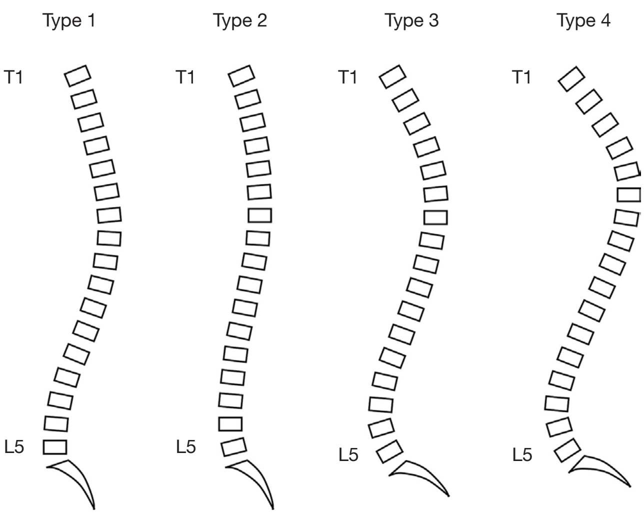

Figure 2 Typical figure of Roussouly classification.

spine anteroposterior and lateral X-ray radiographs preoperatively in a standardized position (17) to assess the preoperative and postoperative sagittal alignment parameters and Roussouly classification (*Figure 1*). The left-right oblique and lateral flexion–extension bending position of the lumbar vertebrae on X-ray plain film, computed tomography (CT) scans, and magnetic resonance imaging (MRI) images were also acquired to evaluate the patient's condition and to formulate the surgical approach for the patient. Anteroposterior standing full-length spine and lateral X-ray radiographs were performed on the participant's last follow-up last visit in order to assess Roussouly classification after lumbar operation.

An independent experienced spine surgeon reviewed the clinical data, which included general data (gender, age, and follow-up time); the patient's diagnosis; the number of surgery segments needed; and the preoperative and postoperative sagittal alignment parameters, including pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL), thoracic kyphosis (TK), and sagittal vertical axis (SVA). Two experienced spinal surgeons measured the radiographic parameters via Surgimap version 2.2.13.1 software (The Physician Driven Image Solution, Nemaris Inc., New York, NY, USA) on Windows. The interobserver agreement was above 0.9. The 2 surgeons classified the preoperative and postoperative anatomy morphology of the lumbar spine into 4 types as described by Roussouly *et al.* (9): type 1 lordosis (the SS is less than 35°, and the apex of the LL is located in the center of the L5 vertebral body), type 2 lordosis (the SS is less than 35°, and the apex of the LL is located at base of the L4 vertebral body), type 3 lordosis (the SS is between 35° and 45°), and type 4 lordosis (the SS is greater than 45°) (*Figure 2*). The final Roussouly type was determined after the 2 surgeons reached agreement.

Clinical evaluation

Clinical evaluation was conducted by self-questionnaires, including the visual analogue scale for low back pain (VAS-B), VAS for leg pain (VAS-L), and the Oswestry disability index (ODI) (18). All the patients were asked to complete self-questionnaires preoperatively and postoperatively at 6-month follow-up.

Statistical analysis

Statistical analyses were conducted using SPSS 19.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics are expressed as mean ± standard deviation (SD), minimum, and maximum. Differences in the measurement data were compared with *t* test or 1-way analysis of variance (ANOVA). A chi-squared test or Kruskal-Wallis H test was used to compare categorical data. Statistical significance was set at $P<0.05$. Data were anonymously recorded in Excel 2013 (Microsoft Corp., Richmond, WA, USA).

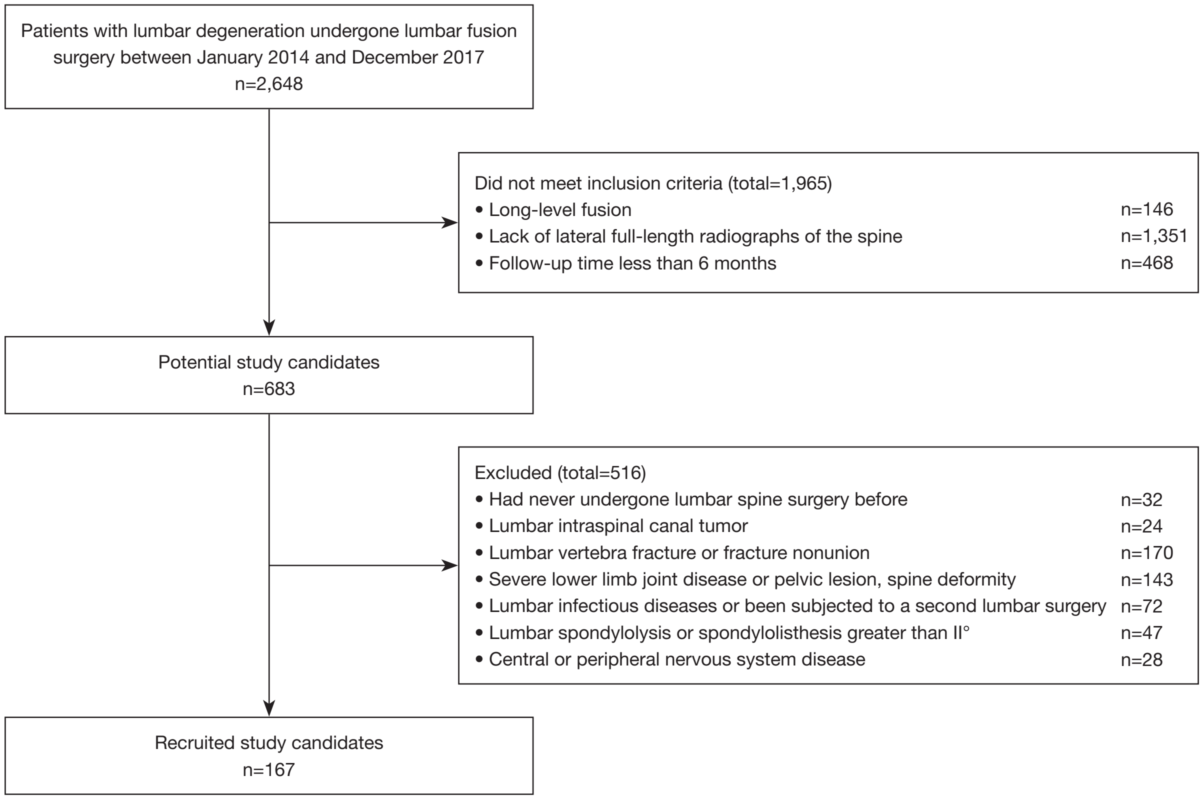

Figure 3 Recruitment of patients.

Results

Figure 3 summarizes the recruitment of patients. As shown in *Table 1*, 167 patients were involved in this study, including 86 males and 81 females, whose mean age was 52.0±12.4 [14–88] years. According to preoperative Roussouly classification, 31 patients were valued as type 1 (18.6%) and were aged 55.5±13.5 [24–80] years, 77 patients were valued as type 2 (46.1%) and were aged 50.7±12.4 [23–88] years, 44 patients were valued as type 3 (26.3%) and were aged 51.6±12.0 [14–74] years, and 15 patients were valued as type 4 (9.0%) and were aged 53.3±10.6 [36–73] years. Patients' preoperative ODI, VAS-B, and VAS-L scores were 51.1±5.9, 7.0±1.4, and 7.1±1.6, respectively. A total of 103 patients underwent a single-segment operation, and 64 received a multiple-segment operation. The total follow-up time was 11.5±6.9 months. The differences in the general data described above among the 4 Roussouly types were not statistically significant. Of the 167 patients, 104 patients' first diagnoses were lumbar disc herniation, 40 were lumbar spinal stenosis, and 23 were lumbar spondylolisthesis.

According to the postoperative Roussouly classification, 29 patients were assessed as type 1 (17.4%) and were aged 53.1±15.3 [24–88] years, 50 patients were assessed as type 2 (29.9%) and were aged 49.2±13.5 [14–80] years, 69 patients were assessed as type 3 (41.3%) and were aged 53.1±10.7 [27–78] years, and 19 patients were assessed as type 4 (11.4%) and were aged 54.1±9.3 [36–68] years. Patients' ODI, VAS-B, and VAS-L scores at the 6-month follow-up were 26.0±6.8, 1.3±1.0, and 1.3±1.0, respectively. The preoperative and postoperative ODI, VAS-B, and VAS-L scores were significantly different ($P<0.001$). The general data of patients of different postoperative Roussouly types are shown in *Table 2*. During follow-up, no mechanical complications were found. One patient experienced poor surgical wound healing without infection, and the wound healed well after restitching.

When compared to the preoperative Roussouly type, the Roussouly type in 75 patients' had changed by the time of their last follow-up, among whom were 11 preoperative Roussouly type 1 patients, 38 preoperative Roussouly type 2 patients, 20 preoperative Roussouly type 3 patients, and

Table 1 Patients' general data before surgery (mean ± SD)

	Preoperative Roussouly classification type				Total (n=167)	P value
	Type 1 (n=31)	Type 2 (n=77)	Type 3 (n=44)	Type 4 (n=15)		
Sex ratio (M/F)	2.1	0.9	1.0	0.9	1.1	0.246
Age (years)	55.5±13.5	50.7±12.4	51.6±12.0	53.3±10.6	52.0±12.4	0.325
Follow-up (months)	12.2±7.1	11.3±6.6	11.9±8.1	9.5±3.3	11.5±6.9	0.640
ODI score	51.9±7.1	50.5±5.2	51.4±6.0	51.2±6.2	51.1±5.9	0.699
VAS-B score	6.7±1.6	7.1±1.4	7.1±1.3	7.2±1.3	7.0±1.4	0.566
VAS-L score	6.7±1.9	7.2±1.5	7.1±1.4	6.9±1.6	7.1±1.6	0.470
Segment, n						0.264
Single segment	15	47	30	11	103	
Multiple segments	16	30	14	4	64	

SD, standard deviation; n, number of patients; M, male; F, female; ODI, Oswestry disability index; VAS-B, visual analogue scale low back pain; VAS-L, visual analogue scale leg pain.

Table 2 Patients' general data after surgery (mean ± SD)

	Postoperative Roussouly classification type				Total (n=167)	P value
	Type 1 (n=29)	Type 2 (n=50)	Type 3 (n=69)	Type 4 (n=19)		
Sex ratio (M/F)	1.4	0.9	1.1	1.1	1.1	0.749
Age (years)	53.1±15.3	49.2±13.5	53.1±10.7	54.1±9.3	52.0±12.4	0.277
Follow-up (months)	10.4±5.5	12.6±7.7	11.4±7.5	10.3±2.7	11.5±6.9	0.454
ODI score	26.6±6.5	25.1±7.2	26.5±7.0	25.4±5.9	26.0±6.8	0.654
VAS-B score	1.3±1.0	1.3±1.0	1.4±1.0	1.2±0.9	1.3±1.0	0.795
VAS-L score	1.2±0.9	1.3±1.0	1.4±1.0	1.1±0.9	1.3±1.0	0.688
Segment, n						0.735
Single segment	17	33	40	13	103	
Multiple segments	12	17	29	6	64	

SD, standard deviation; n, number of patients; M, male; F, female; ODI, Oswestry disability index; VAS-B, visual analogue scale low back pain; VAS-L, visual analogue scale leg pain.

6 preoperative Roussouly type 4 patients. The rate of type changing in different preoperative Roussouly types after operation was not significantly different (P=0.192). The change in Roussouly classification after surgery is shown in *Figure 4*. The distribution of preoperative Roussouly types in different postoperative Roussouly type groups is shown in *Table 3*, and the difference was significant (P<0.001).

The sagittal alignment parameters changed after lumbar surgery. The preoperative values for PT, SS, LL, TK, and SVA were 17.2°±8.9°, 32.5°±9.7°, 42.3°±15.2°, 21.7°±11.0°, and 9.9±35.9 mm, respectively; the postoperative values for these parameters were 13.5°±7.7° (P<0.001), 35.7°±8.7° (P=0.002), 48.1°±12.8° (P<0.001), 25.0°±9.7° (P=0.005), and –2.7±22.5 mm (P<0.001), respectively The preoperative and postoperative PI values were 49.6±10.7 and 48.9±11.3, respectively, and the difference was not significant (P=0.591). The change in anatomical sagittal alignment parameters is shown in *Figure 5*.

Some preoperative sagittal alignment parameters were determined to be associated with postoperative

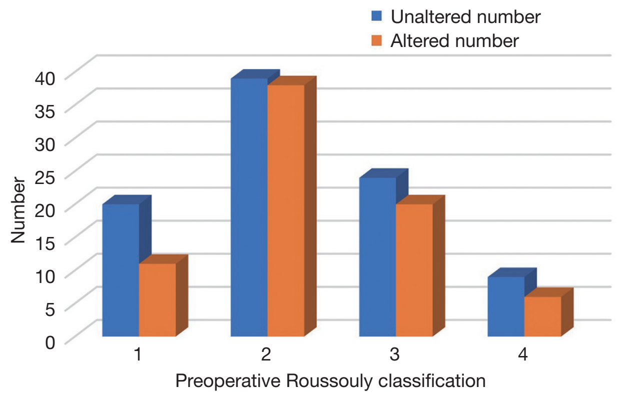

Figure 4 Change of Roussouly classification after surgery.

Table 3 Change of Roussouly classification type

	Roussouly classification after surgery				Total	P value
	1	2	3	4		
Roussouly classification before surgery						<0.001[a]
1	20	4	7	0	31	
2	4	39	32	2	77	
3	5	7	24	8	44	
4	0	0	6	9	15	
Total	29	50	69	19	167	

a, statistically significant difference.

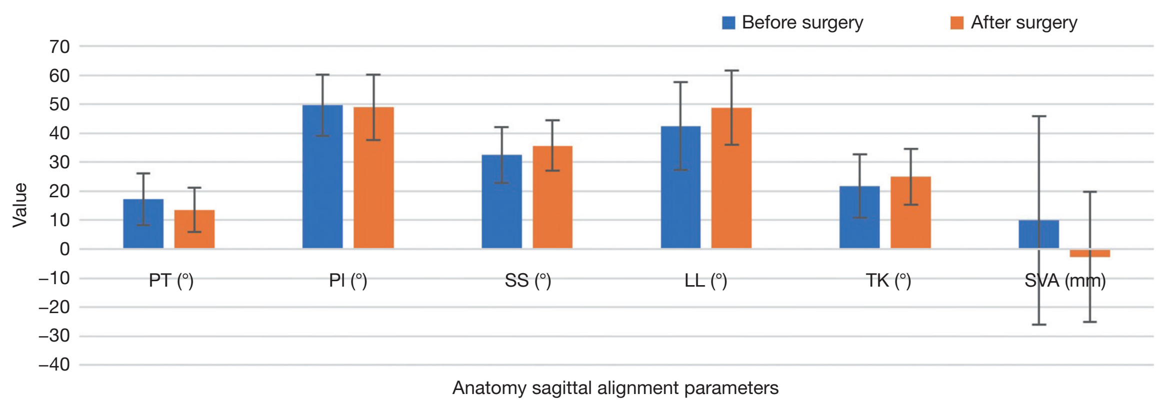

Figure 5 Changes of anatomical sagittal alignment parameters after surgery PT, pelvic tilt; PI, pelvic incidence; SS, sacral slope; LL, lumbar lordosis; TK, thoracic kyphosis; SVA, sagittal vertical axis.

Roussouly type. Patients' PT, TK, and SVA values showed poor correlations with Roussouly type after the lumbar fusion surgery, whereas the P value of PI, SS, and LL in different postoperative Roussouly types was less than 0.001. Preoperative radiographic parameters for each type of postoperative Roussouly classification are presented in *Table 4*.

Discussion

The Roussouly classification system has been a valuable tool to evaluate patients' sagittal alignment and to predict spinal degeneration (19-23). The association between Roussouly classification and the characteristics of lumbar degeneration has been described by Zhao *et al.* (19). The risks of advanced disc degeneration are higher for patients with lumbar spine morphologies of Roussouly type 1 or type 2, especially for those with type 2 lumbar spine. Meanwhile, high-grade degeneration of the facet joint tends to occur in those with type 3 and especially type 4 lumbar spine. Moreover, Roussouly classification has been validated by many researchers as an indicator of surgical outcome. Zhang *et al.* (20) suggest that postoperative Roussouly classification can be seen as a predictor of problems in distal junctional after long instrumented spinal fusion. Passias *et al.* (21,22) compared the preoperative and postoperative spine sagittal alignment in adult patients with spinal deformity and reported that patients who both matched the Roussouly type and showed improvement in Schwab modifiers had superior patient-reported outcomes. Another study in healthy adults revealed that the specific lumbar shape can be affected by the sacral morphology (23), but which parameters are associated with postoperative Roussouly type remains unclear.

Table 4 Preoperative radiographic parameters for postoperative Roussouly type (mean ± SD)

Preoperative radiographic parameter	Postoperative Roussouly classification type				Total	P value
	1	2	3	4		
PT (°)	14.8±9.0	19.6±8.4	17.1±9.0	14.8±8.9	17.2±8.9	0.069
PI (°)	39.7±8.7	47.6±6.7	52.6±10.8	58.8±8.8	49.6±10.7	<0.001[a]
SS (°)	25.3±8.7	28.1±7.7	35.6±7.4	43.9±8.0	32.5±9.7	<0.001[a]
LL (°)	34.4±13.7	36.6±14.2	45.7±13.1	56.8±13.0	42.3±15.2	<0.001[a]
TK (°)	24.0±11.6	20.8±12.1	20.9±10.5	23.6±8.8	21.7±11.0	0.488
SVA (mm)	2.3±21.3	15.7±40.3	9.1±38.6	9.3±30.4	9.9±35.9	0.453

[a], statistically significant difference. SD, standard deviation; PT, pelvic tilt; PI, pelvic incidence; SS, sacral slope; LL, lumbar lordosis; TK, thoracic kyphosis; SVA, sagittal vertical axis.

In this study, the posterior lumbar fusion surgery was shown to be an effective method for addressing certain lumbar diseases according to ODI and VAS scores. Patients with different Roussouly types demonstrated clinical improvement within a minimum of 6 months' follow-up. Moreover, fusion surgery was influential in the spinal sagittal alignment. Except for the fixed anatomical parameters of PI (24), all radiographic parameters involved in our study changed after the operation, particularly SS and LL. Along with the change of sagittal alignment parameters, the distribution of patients' Roussouly type also varied. A lack of change in Roussouly type was most common after a posterior lumbar fusion surgery, followed by a change to an adjacent type, and then a change to a nonadjacent type.

After comparing the patients' Roussouly type classifications before and after the operation, we found that patient's preoperative Roussouly type classification was not related to whether the classification changed or not. It seems that the postoperative Roussouly type is independent of the preoperative Roussouly type. However, when analyzing the distribution of preoperative Roussouly types in the different postoperative Roussouly type groups, we found that specific postoperative classification was relevant to an individual's preoperative Roussouly type.

Preoperative Roussouly type is not the only factor that can determine a patient's Roussouly type after a lumbar operation. Our study suggests that parameters of preoperative PI, SS, and LL are also relevant to the postoperative Roussouly type. Since Roussouly type is classified by SS and the apex of the LL (9), the impact of SS and LL should be seen as the foundation of the classification. Thus, considering the stability of PI before and after the surgery and the incremental value of preoperative PI in the 4 postoperative Roussouly types, the parameter of preoperative PI is significant for predicting a patient's Roussouly classification after posterior lumbar fusion surgery. The analysis of the range of preoperative PI values of each postoperative Roussouly type group indicates that PI value increases in steps, which is conducive to the prediction of postoperative Roussouly type. Patients with a preoperative PI value of 39.7±8.7 tended to acquire Roussouly type 1 after the operation, patients with a preoperative PI value of 47.6±6.7 tended to acquire Roussouly type 2, patients with a preoperative PI value of 52.6±10.8 tended to acquire Roussouly type 3, and patients with a preoperative PI value of 58.8±8.8 tended to acquire Roussouly type 4.

Roussouly classification has a critical correlation with the development of degenerative spinal diseases, which is related to the different biomechanical adaptations of the spine rather than the biochemical differences of the degenerative discs (15,25). Type 4 individuals, for example, are at risk of spondylolisthesis through L5 isthmic lysis by a "sliding" mechanism. Most studies on Roussouly classification have focused on its effect on long-level fusion surgeries, such as spinal deformity surgery. However, research into patients with a short-level fusion (fusion level ≤3) due to degenerative lumbar diseases is rare. Our study focused on describing the pattern and influencing factors of Roussouly classification change after short-level transforaminal lumbar interbody fusion surgery in order to provide reference data and help guide further research on the relationship between the clinical results of this surgery and Roussouly classification.

Limitations

The present study has some limitations. Our study revealed that preoperative Roussouly type and PI value may determine a patient's postoperative Roussouly type. However, the exact relationship between Roussouly type and PI value remains unclear, and further research is needed. Furthermore, the number of patients with Roussouly type 4 was inconsistent with the data reported elsewhere, which suggests a potential bias. Preoperatively and postoperatively, the type 4 patients constituted 9.0% and 11.4% of all 167 patients, respectively, whereas type 4 patients accounted or 30.0% of the population described by Roussouly *et al.* (9). A skewed distribution of the 4 types might misestimate a potential statistical difference. Additionally, although different postoperative Roussouly types may lead to differences in potential degeneration in the long term, our study was restricted in its follow-up time, and it is unclear that the exact long-term effect of postoperative Roussouly types on patients with short-level fusion lumbar surgeries.

Conclusions

The Roussouly classification changes after posterior lumbar fusion surgery. This change is independent of gender, age, follow-up time, and the number of surgical segments. The preoperative Roussouly type and PI value are essential in predicting a patient's postoperative Roussouly type.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-22-365/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-22-365/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional review board of the First Affiliated Hospital, Air Force Medical University, and individual consent for this retrospective analysis was waived.

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