Original Article

Evaluation and analysis of surgical treatment for single-level or multi-level lumbar degenerative disease based on radiography

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Background: Radiography has a low level of radiation exposure while providing valuable information. Due to its cost effectiveness and widespread availability, the preoperative radiographic imaging examination is a valuable approach for assessing patients with spinal disease. This study aimed to examine the influence of preoperative X-ray evaluation on the surgical treatment of patients with single- or multi-level lumbar degenerative disease (LDD).

Methods: A retrospective cohort analysis was conducted of 172 patients diagnosed with LDD who underwent transforaminal lumbar interbody fusion (TLIF) or posterior lumbar interbody fusion (PLIF) surgery between December 2021 and February 2023 at the Shanghai Changzheng Hospital. Various parameters were measured on preoperative radiographs, including the iliac crest height, median iliac angle (MIA), lumbar lordosis (LL), intervertebral facet joint degeneration, lumbosacral angle (LSA), intervertebral foramen height (IFH), and surgical segment. The surgical treatment was evaluated based on the operative time, intraoperative blood loss, and postoperative complications. A correlation analysis and independent sample *t*-tests were used to assess the relationship between preoperative radiographic variables and surgical treatments. Further, a multivariate linear regression analysis was employed to identify the risk factors affecting the clinical outcomes.

Results: The correlation analysis and *t*-test results showed that the MIA, height of the iliac crest, intervertebral facet joint degeneration, and surgical segment were significantly correlated with the surgical treatments ($P<0.05$). Specifically, the height of the iliac crest, intervertebral facet joint degeneration, and surgical segment were positively correlated with the surgical treatments. Conversely, the MIA was negatively correlated with the surgical treatments. However, no significant differences were observed between the IFH, LSA, and LL in relation to posterior lumbar surgery ($P>0.05$). The multiple linear regression analysis showed that the height of the iliac crest, MIA, intervertebral facet joint degeneration, and surgical segment were independent factors affecting the surgical treatments of patients with single- or multi-level LDD. These findings highlight the importance of considering these factors when planning and performing lumbar surgery.

Conclusions: The measurements taken from radiographs, including the height of the iliac crest, MIA, intervertebral facet joint degeneration, and surgical segment, demonstrate potential influences on the treatment of single- and multi-level lumbar spine surgery. These variables can be captured in plain film imaging and can provide valuable insights into the surgical procedure and offer guidance for the operation. By analyzing these radiographic measurements, surgeons can gain a better understanding of a patient's condition and tailor the surgical approach accordingly, thus optimizing the outcomes of the surgery.

Keywords: Surgical treatment; multi-level lumbar surgery; radiography; median iliac angle (MIA); intervertebral facet joint degeneration

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Introduction

With the aging of the population, the incidence of lumbar degenerative disease (LDD) is increasing (1). Transforaminal lumbar interbody fusion (TLIF) and posterior lumbar interbody fusion (PLIF) have become the standard and widely accepted treatments for patients with LDD, which includes spinal stenosis, lumbar spondylolisthesis, lumbar disc herniation, and degenerative scoliosis (2,3) when conservative measures have failed for at least six months (4). Many researchers have identified risk factors affecting surgical treatment, including old age, obesity, and anatomical structure, but no consensus has been reached (5). In addition, the importance of preoperative radiography references is often overlooked; however, such references provide an important basis for clinicians to understand a patient's condition and make surgical management decisions.

With the continuous development of imaging technology, clinicians have more preoperative references, and with the help of appropriate imaging methods, clinicians can obtain disease-related information (6). In current clinical diagnosis and treatment, X-ray, computed tomography (CT), and magnetic resonance imaging (MRI) play a crucial role in evaluating spinal surgery, allowing clinicians to predict the difficulty of the surgery preoperatively (7,8). Each imaging method has its own advantages. For example, CT has advantages in ossification imaging, while MRI is currently an essential method for diagnosing spinal diseases, with high clarity and absolute advantages in soft tissue imaging (9,10). However, CT and MRI also have disadvantages, including high costs, time-consuming processes, and high radiation exposure (11).

The guiding role of preoperative radiography in surgery is often ignored. The severity of spinal diseases can be accurately assessed through X-ray imaging, which is routinely used to evaluate LDD (12,13). X-ray is a non-invasive and easily accessible imaging method. Thus, patients do not need to wait too long for the examination. In addition, compared with some of the more sophisticated imaging methods, such as MRI or CT, radiography is usually less costly and relatively economical for patients. Many of the above factors led us to conclude that X-ray could play an important role and be of significance in the preliminary evaluation of surgical treatment. However, we found that clinicians currently do not pay enough attention to preoperative X-ray. Given that X-ray is an extremely convenient and universal imaging examination, this study aimed to explore the relationship between preoperative X-ray measurement variables and the surgical treatments of single- and multi-level LDD patients. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-23-1108/rc).

Methods

Inclusion and exclusion criteria

To be eligible for inclusion in this study, the patients had to meet the following inclusion criteria: (I) have undergone single- or multi-level lumbar surgery; (II) have a TLIF or PLIF surgical type; (III) have standing posterior-anterior and lateral preoperative X-ray films available; and (IV) have undergone the surgery by the same senior clinician (G.S.). Patients were excluded from the study if they met any of the following exclusion criteria: (I) had a previous history of severe spinal trauma; (II) had a history of long-term use of anticoagulants or anticholinergic or adrenergic drugs; (III) had congenital spinal deformity, tumor, tuberculosis, or metabolic bone disease; (IV) had a comorbid serious underlying disease (e.g., diabetes mellitus or a history of stroke); (V) had a body mass index (BMI) >35 kg/m^2; (VI) had undergone revision surgery of the lumbar spine; (VII) had undergone pediatric spinal surgery; and/or (VIII) had any serious general illness (e.g., heart failure or acquired immune deficiency syndrome).

Using the unified inclusion and exclusion criteria, two evaluators independently screened the patients' information; any disagreements were resolved by discussion or by consulting a third researcher.

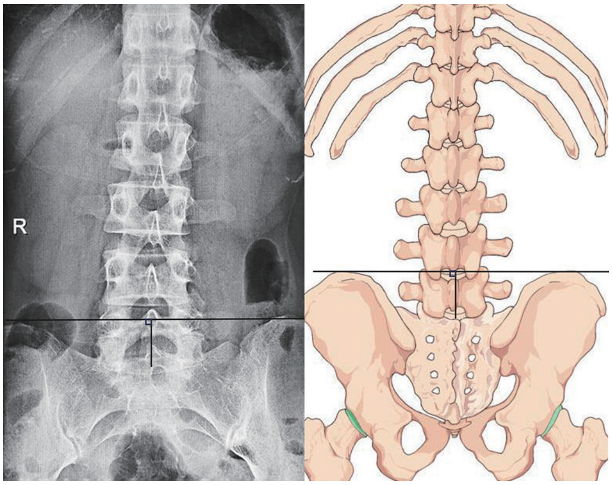

Figure 1 Measurement of the height of the iliac crest. R represents the right side of the patient.

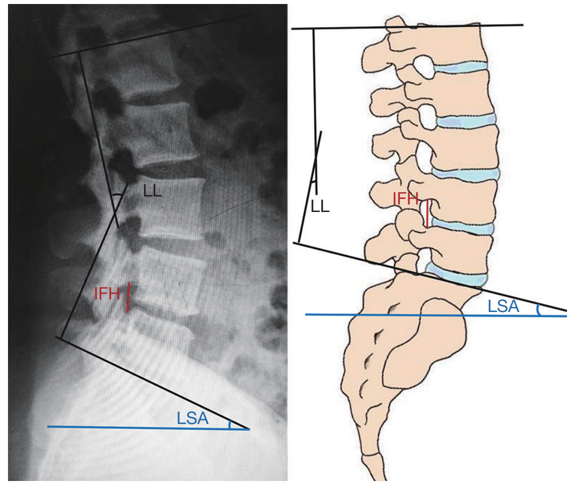

Figure 3 Measurement of the LL, intervertebral facet joint degeneration, LSA, and IFH. LL, lumbar lordosis; IFH, intervertebral foramen height; LSA, lumbosacral angle.

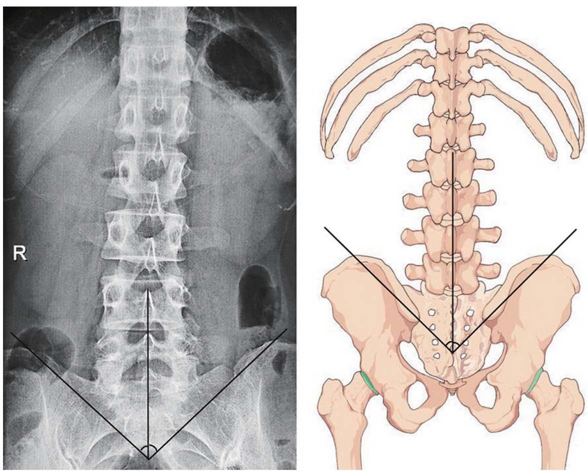

Figure 2 Measurement of the median iliac angle. R represents the right side of the patient.

Radiography

The following radiographic variables were analyzed: the height of the iliac crest, median iliac angle (MIA), lumbar lordosis (LL), intervertebral facet joint degeneration, lumbosacral angle (LSA), intervertebral foramen height (IFH), and surgical segment. (I) Height of the iliac crest: on the anteroposterior radiograph of the lumbar spine, the height of the iliac crest was measured as the distance between the intercrestal line and the midpoint of the top of the sacral vertebral body (14) (*Figure 1*). (II) MIA: this angle was determined by measuring the angle between the line connecting the highest point of the iliac crest and the posterior superior iliac spine, and the central sacral vertical line (CSVL) (15). The CSVL was defined as a straight line passing through the midpoint of the upper edge of S1 and perpendicular to the horizontal ground. The MIA was calculated as an average of the measurements obtained from both the left and right sides (16,17) (*Figure 2*). (III) LL: this was measured as the angle between the superior endplate of L1 and the superior endplate of S1 (18,19) (*Figure 3*). (IV) Intervertebral facet joint degeneration: this was defined as moderate to severe hyperplasia of the intervertebral joint, resulting in difficult in distinguishing between intervertebral facet joint gaps. A normal intervertebral facet joint was defined as a joint with no degeneration and in which the intervertebral facet joint gap could be distinguished (15) (*Figure 4*). (V) LSA: this was defined as the angle formed along the superior endplate of S1 relative to the horizontal plane (20) (*Figure 3*). (VI) IFH: this parameter was measured as the distance between the lower margin of the superior pedicle and the upper margin of the inferior pedicle (21) (*Figure 3*). To minimize errors, two independent orthopedic surgeons evaluated the radiographic data to reduce interobserver and intraobserver discrepancies.

Follow-up

Follow-up examinations were conducted on the 10th day after the lumbar surgery, followed by monthly check-ups.

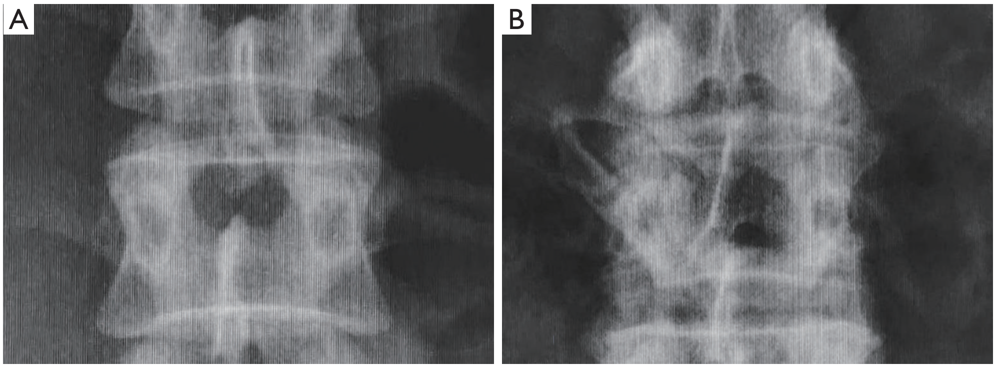

Figure 4 Sample figure of intervertebral facet joint degeneration. (A) A normal intervertebral facet joint; (B) an intervertebral facet joint with degeneration.

After three months, subsequent follow-up examinations were scheduled at 3-month intervals. For each follow-up visit, the patients were contacted via telephone for an interview and asked to complete an assessment questionnaire.

Statistical analysis

For the multi- or single-level lumbar surgery, preoperative and postoperative Oswestry disability index (ODI) and visual analog scale (VAS) scores were obtained. The surgical treatment was evaluated based on the operation time, the amount of blood loss intraoperatively, and the postoperative complications. Postoperative complications included surgical site infection, cerebrospinal fluid leakage, worsening postoperative symptoms, neurological deterioration, and cage migration. We hypothesized that a variable measured on radiographs may influence spinal surgical treatment if it was associated with operative time and blood loss volume simultaneously ($P<0.05$).

The correlations between the measured radiographic variables, such as the height of the iliac crest, MIA, LSA, LL, IFH, and surgical segment, and the surgical treatment were assessed using the Spearman rank correlation test if the normality test (i.e., the Kolmogorov-Smirnov test) was satisfied. The Mann-Whitney U-test (two sided) was used if the normality test failed. A P value less than 0.05 was considered statistically significant. Meanwhile, an independent sample *t*-test (two sided) was used to verify the effects of the surgical type and interbody facet joint degeneration on the surgical treatment. Additionally, the inter-rater reliability of other radiographic measurements, including the MIA, height of the iliac crest, intervertebral facet joint degeneration, LSA, IFH, and LL, were assessed using the intraclass correlation coefficient (ICC). To compare the statistical differences among the three types of LDD, a completely random analysis of variance (ANOVA) was employed. Before the regression analysis, the data were further checked to examine the independence of the observations using the Durbin-Watson statistic. In addition, we also calculated variance inflation factors (VIFs) to evaluate multicollinearity; a VIF less than 5 was considered an acceptable value. A multivariate linear regression analysis was conducted to identify the factors affecting surgical treatment. All the statistical analyses were performed using R version 4.0 (R Foundation for Statistical Computing, Vienna, Austria) and IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA).

Ethical review

The study protocol was approved by the Medical Institutional Review Board of the Shanghai Changzheng Hospital, and every patient signed an informed consent form before participating in the study. All the methods were performed in accordance with the relevant guidelines and regulations. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

Results

A total of 172 patients were identified between December 2021 and February 2023 based on the data of patients from Shanghai Changzheng Hospital. Among them, 141 patients met the inclusion criteria, and 31 patients were excluded due to the exclusion criteria. After at least three months of

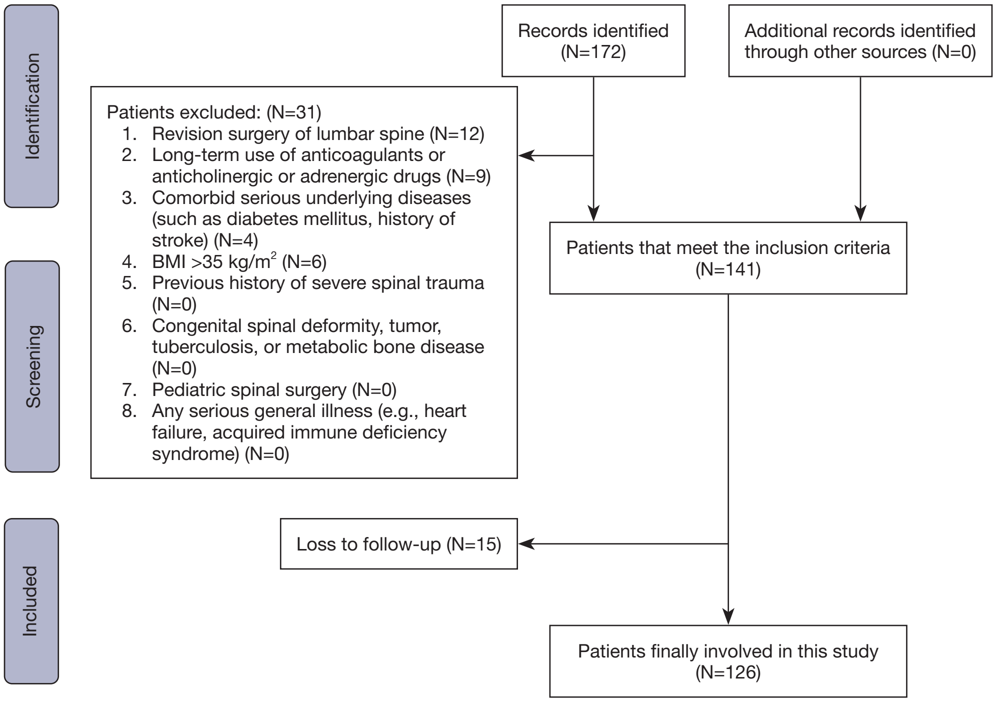

Figure 5 The case collection flowchart. BMI, body mass index.

follow-up, 15 patients were excluded due to loss to follow-up. Ultimately, a total of 126 patients were included in the study, of whom 73 had lumbar disc herniation, 41 had spinal stenosis, and 12 had lumbar spondylolisthesis. The results of the random ANOVA showed that there was no statistical difference between these three groups (P>0.05). Among the patients, 81 underwent TLIF surgery, while the remaining 45 underwent PLIF surgery. The case collection flowchart is shown in *Figure 5*. Patient characteristics are summarized in *Table 1*.

The mean age of the patients was 45.3 years (range, 19–78 years), and women accounted for 48% of all patients. There was no statistically significant difference between the patients in terms of age or sex (P>0.05). At least three months of follow-up showed significant improvement in the patients' functional activity and pain levels. As *Table 1* shows, the VAS and ODI scores showed a significant improvement from 7.4±1.6 preoperatively to 1.9±1.2 postoperatively, and from 72.1±15.4 preoperatively to 35.5±13.2 postoperatively, respectively (P<0.05). In the single-level lumbar surgery group, the average operation time was 86.24±26.44 minutes and the mean blood loss during surgery was 233.9±62.04 mL; in the double-level lumbar surgery group, the average operation time was 115.25±31.71 minutes and the mean blood loss during operation was 351.04±62.65 mL; while in the triple-level lumbar surgery group, the average operation time was 139.05±27.83 minutes and the mean blood loss during operation was 440.94±60.1 mL. Additionally, among the patients, there were six cases of cerebrospinal fluid leakage, 12 cases of worsening postoperative symptoms, four cases of neurological deterioration, and three cases of cage migration. The inter-rater reliability was high for the MIA (ICC: 0.91), height of the iliac crest (ICC: 0.93), LSA (ICC: 0.92), LL (ICC: 0.89), and IFH (ICC: 0.87).

In this study, the univariate correlation analysis showed that the iliac crest height and surgical segment were positively correlated with the operative time. Conversely, the MIA was a negatively correlated with the operative time. However, no statistically significant correlations were found between the operative time and some radiographic variables, such as LSA, LL, and IFH (*Table 2*). The *t*-test analysis showed that there was no statistically significant correlation between the surgical type and operative time, but we found there was a statistically significant correlation between the degeneration of the lumbar facet joints and the operative time (*Table 3*).

In the correlation analysis of the variables and estimated bleeding volume, the surgical segment and MIA were found

Table 1 Summary of patient characteristics

Patient characteristics	Data (N=126)
Lumbar disc herniation	73
Spinal stenosis	41
Lumbar spondylolisthesis	12
Age (years)	45.3
Sex	66 males, 60 females
Operation time (min)	
Single-level	86.24±26.44
Double-level	115.25±31.71
Triple-level	139.05±27.83
Blood loss (mL)	
Single-level	233.9±62.04
Double-level	351.04±62.65
Triple-level	440.94±60.1
Preoperative VAS	7.4±1.6
Postoperative VAS at the three-month follow-up	1.9±1.2[a]
Preoperative ODI	72.1±15.4
Postoperative ODI at the three-month follow-up	35.5±13.2[b]
Complications	
Cerebrospinal fluid leakage	6
Postoperative symptoms worsen	12
Neurological deterioration	4
Cage migration	3

Data are presented as the mean ± standard deviation or n. [a], compared to preoperative VAS, P<0.01; [b], compared to preoperative ODI, P=0.03. VAS, Visual analog scale; ODI, Oswestry disability index.

Table 2 Correlation coefficients and statistical differences of the measurement parameters on radiography (operation time)

Parameters	Correlation coefficient (r)	P value
MIA	–0.3977	<0.001*
Iliac crest height	0.1813	0.042*
LSA	0.0121	<0.893
LL	0.0032	>0.972
IFH	–0.077	>0.389
Surgical segment	0.5885	<0.001*

*, indicates a statistically significant result. MIA, median iliac angle; LSA, lumbosacral angle; LL, lumbar lordosis; IFH, intervertebral foramen heigh.

Table 3 *t*-test for surgical type and intervertebral facet joint degeneration

Parameters	P value
For operative time	
Surgical type	0.954
Intervertebral facet joint degeneration	0.043*
For blood loss	
Surgical type	0.900
Intervertebral facet joint degeneration	0.131

*, indicates a statistically significant result.

Table 4 Correlation coefficients and statistical differences of the measurement parameters on radiography (estimated blood loss)

Parameters	Correlation coefficient (r)	P value
MIA	–0.266	0.003*
Iliac crest height	0.063	0.4837
LSA	–0.023	0.801
LL	0.051	0.568
IFH	–0.063	0.480
Surgical segment	0.812	<0.001*

*, indicates a statistically significant result. MIA, median iliac angle; LSA, lumbosacral angle; LL, lumbar lordosis; IFH, intervertebral foramen height.

to be significantly correlated with intraoperative blood loss. However, the iliac crest height, LSA, LL, and IFH parameters were not found to be significantly correlated with intraoperative blood loss (*Table 4*). Meanwhile, the independent sample *t*-test revealed no statistically significant correlation between the type of surgery, intervertebral facet joint degeneration, and the estimated blood loss (*Table 3*).

After conducting the residual analysis to analyze various variables, a first-order positive autocorrelation was detected for both the operative time (Durbin-Watson statistic =1.108) and estimated blood loss (Durbin-Watson statistic =1.210) models using the Durbin-Watson statistic, and the final models were adjusted for autocorrelation. In addition, the VIFs were used to detect multicollinearity, and all variables had VIF values less than 5; the mean VIF value of the final

Table 5 The multiple linear regression analysis between the parameters and single-level or multi-level lumbar surgery in terms of the operative time

Independent variable	Regression coefficient	95% confidence interval	P value
Iliac crest height	0.762	(0.471, 1.053)	<0.001*
MIA	–1.142	(–1.4652, –0.818)	0.004*
Intervertebral facet joint degeneration	12.262	(3.986, 20.538)	<0.001*
LSA	0.169	(–0.260, 0.598)	0.437
LL	–0.081	(–0.397, 0.234)	0.611
IFH	–0.663	(–1.708, 0.382)	0.212
Surgical segment	28.504	(23.451, 33.556)	<0.001*
Surgical type	–0.357	(–8.747, 8.033)	0.933

*, indicates a statistically significant result. MIA, median iliac angle; LSA, lumbosacral angle; LL, lumbar lordosis; IFH, intervertebral foramen height.

Table 6 The multiple linear regression analysis between the parameters and single-level or multi-level lumbar surgery in terms of the estimated blood loss

Independent variable	Regression coefficient	95% confidence interval	P value
Iliac crest height	1.735	(1.097, 2.372)	<0.001*
MIA	–2.188	(–2.896, –1.479)	<0.001*
Intervertebral facet joint degeneration	29.131	(11.012, 47.251)	0.0019*
LSA	0.324	(–0.615, 1.263)	0.496
LL	–0.044	(–0.734, 0.647)	0.901
IFH	–0.9275	(–3.216, 1.361)	0.424
Surgical segment	108.3852	(97.322, 119.448)	<0.001*
Surgical type	3.515	(–14.855, 21.885)	0.705

*, indicates a statistically significant result. MIA, median iliac angle; LSA, lumbosacral angle; LL, lumbar lordosis; IFH, intervertebral foramen height.

model was 1.024. Thus, there was no multicollinearity between the independent variables. The multivariate linear regression analysis showed that some variables, such as the MIA, height of the iliac crest, intervertebral facet joint degeneration, and surgical segment, were statistically significantly associated with operative time and blood loss volume simultaneously (*Tables 5,6*). Therefore, these variables appeared to be factors influencing spinal surgical treatment. However, the LSA, LL, IFH, and the type of surgery showed no 'statistically significant correlation with the clinical outcomes in terms of the operation time and estimated blood loss volume (P>0.05).

Discussion

LDD is a prevalent condition that affects the spine (22,23). The number of individuals worldwide who have to undergo PLIF or TLIF surgery to treat this condition continues to increase. However, debate continues as to surgical treatment evaluations for lumbar interbody fusion surgery. Advancements in imaging technology have significantly contributed to the diagnosis and treatment of LDD. X-ray images, which are cost effective and readily available, have become increasingly vital in this respect (24). They offer a low radiation exposure option while providing valuable information, making them an indispensable tool for assessing the spine. Moreover, radiography is capable of revealing the spinal alignment and providing a comprehensive view of the bone structure (25). By using preoperative radiographic imaging, various factors can be identified hat may aid in stratifying patients and may ultimately enhance surgical treatment and the long-term prognosis of patients.

In our previous studies, we found that some radiographic indicators have a certain effect on the treatment of single-level lumbar surgery. Thus, we sought to examine whether these indicators were also applicable to multi-level lumbar surgery. In this study, we also included additional parameters, such as the surgical segment, surgical type, and LL.

There are many reasons for difficulties in spinal surgery, including the pathological condition and anatomical condition of the spine. In the local anatomy of the lumbar spine, we discovered the relatively novel concept of the MIA. The erector spinae, quadratus lumborum, longissimus thoracis, iliocostalis, and psoas muscles are all distributed in this anatomical structure (26,27). In some individuals with a large MIA, it is relatively easy to pull these muscles outward to achieve a better surgical field of view (28). This facilitates the surgical procedure, reduces the surgical difficulty, and improves the surgical outcomes. In the present study, we observed a correlation between the height of the iliac crest and surgical treatment. In individuals with a higher iliac crest, surgeons often encounter challenges with intraoperative muscle traction and have a limited surgical field of view (29). The height of the iliac crest was found to have a certain association with the MIA. Typically, individuals with a smaller MIA tend to have a higher iliac crest. MIA can directly reflect the tractable range of the muscle, especially in lower lumbar surgery. In patients with a high iliac crest, intraoperative muscle traction was difficult due to the obstruction caused by the bone at the posterior border of the iliac crest.

In the univariate analysis, we found that the height of the iliac crest and facet joint degeneration had no statistically significant correlation with blood loss; however, in the multivariate analysis, there were statistically significant differences between these variables and the estimated bleeding volume. This might be due to the fact that the amount of blood loss was simultaneously affected by the radiographic variables and surgical segment, which led to bias in the univariate analysis.

This study provided a new approach for clinicians to evaluate the surgical treatment; the parameters reflected in preoperative X-ray imaging can be used to evaluate the operation. Due to the convenience and universality of radiography, our study has great clinical significance, especially for doctors in economically backward areas, and can provide doctors with a general estimate of the difficulty of this operation (30,31).

Our findings suggest that for patients with a small MIA and high iliac crest height, intraoperative hemostasis should be considered during the exposure process, supplemented with appropriate amounts of muscle relaxants, and the incision should be extended if necessary. For patients with severe degeneration of the intervertebral facet joint, due to the large changes in the local anatomical structure, it is often difficult to insert the pedicle screw, which in turn affects the surgical management of such patients (32,33). In traditional lumbar surgery, most doctors are accustomed to following the sequence of nail placement, decompression, and fusion. For these patients, combined with a large amount of clinical experience, we believe that the inferior articular process of the upper lumbar spine at the diseased segment should be excised, and the medial wall of the pedicle should be fully exposed to achieve pedicle screw placement under direct vision; that is, decompression should be performed first, followed by nail placement. The influence of the surgical segment on the surgical treatment requires the surgeon to identify the different placement angles of the pedicle screws at different levels and improve their own surgical technique. By adopting this approach, we believe that multi-level degenerative diseases of the lumbar spine can be effectively treated.

This study had a number of limitations, such as the small number of included cases. Large sample and multicenter studies should be conducted in the future to further verify the rationality of our conclusion. In addition, many variables in the statistical methods did not meet the normal distribution assumption, which might have led to some bias in the results.

Conclusions

In the present study, some variables, including the height of the iliac crest, MIA, intervertebral facet joint degeneration, and surgical segment, were shown to have a potential influence on the treatment of single- and multi-level lumbar spine surgery. Thorough preoperative evaluation of X-ray scans can play a crucial role in enhancing surgical treatments for patients diagnosed with LDDs.

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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-23-1108/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-23-1108/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. All the methods were performed in accordance with the relevant guidelines and regulations. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study protocol was approved by the Medical Institutional Review Board of the Shanghai Changzheng Hospital, and every patient signed an informed consent form before participating in this study.

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