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Comparison of the clinical efficacy of the Wiltse paraspinal approach and O-arm navigation for the treatment of thoracolumbar fractures

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Abstract

Background: To evaluate the clinical efficacy of the Wiltse paraspinal approach and percutaneous pedicle screw placement under O-arm navigation for the treatment of thoracolumbar fracture.

Methods: We enrolled a total of 54 patients with neurologically intact thoracolumbar fracture who received minimally invasive treatment. Among these, 28 patients were treated with pedicle screw fixation through the Wiltse paraspinal approach (WPSF), and another 26 were received percutaneous pedicle screw fixation under O-arm navigation (OPSF). Statistical methods were used to perform a detailed comparison of clinical outcomes, radiologic findings and complications between the two groups obtained preoperatively, postoperatively and at last follow-up.

Results: There were no significant differences between the two groups in terms of the intraoperative bleeding, length of incision, postoperative hospitalization durations or accuracy rate of pedicle screw placement ($p>0.05$). Visual analog scale (VAS) scores, Oswestry disability index (ODI) scores, local Cobb angle (LCA), vertebral wedge angle (VWA) and R value were notably improved after surgery, though no clear discrepancy between the groups at each time point ($p>0.05$). However, the OPSF group had a longer operation time and greater surgical expenditure than the WPSF group ($p<0.05$).

Conclusions: Both WPSF and OPSF were safe and effective for the treatment of thoracolumbar fracture. Although the two groups showed favorable clinical and radiologic outcomes through the final follow-up, we recommended the minimally invasive WPSF given its lower duration of surgery and medical costs. A randomized controlled study of high-quality and with a larger sample size is required to comfirm our findings in the future.

Background

Traumatic spinal fractures occur frequently in the weakest biomechanical location of the thoracolumbar junction (T10-L2), which accounts for 90% of all spine fractures [1,2]. The traditional surgical treatment for thoracolumbar fracture is open posterior pedicle screw instrumentation. However, the operative approach involves detaching the paravertebral muscles from the bone portion of the spine, which can lead to several problems such as increased intraoperative bleeding, soft tissue ischemia, muscle denervation and atrophy, and chronic back pain [3-5].

With the tremendous development of minimally invasive techniques, such as the paraspinal muscular approach through Wiltse space, percutaneous pedicle screw placement under fluoroscopy, and O-arm-based navigation systems for the implantation of pedicle screws, the incidence of the aforementioned approach-related complications can evidently be reduced. As a result, the patient can experience a smaller incision, rapidly reduced pain, shorter hospitalization stay, and a rapid return to life and work [3,5-10]. These techniques fully abided by the concept of Enhancing Recovery After Surgery (ERAS) in orthopedics [11].

Nevertheless, for many minimally invasive techniques, we required a better understanding of the surgical indications to guide the selection of appropriate and better minimally invasive methods. Fan et al. [4] compared the paraspinal muscle approach and percutaneous pedicle screw placement under fluoroscopy for thoracolumbar burst fracture, and found that both surgical methods are safe and reliable; ultimately, they preferred the Wiltse approach as a better choice in terms of radiation exposure, operative cost, learning curve and reduction of kyphosis. In this study, we first performed a comparsion of the Wiltse approach and percutaneous pedicle screw fixation under O-arm navigation for the treatment of thoracolumbar fracture, to study which minimally invasive technique was more beneficial for patients.

Methods

Patient population

Patients with traumatic single-segment thoracolumbar fractures (T10-L2), treated in our hospital between October 2014 and October 2018 were eligible for enrollment in this study. The study complied with the Declaration of Helsinki and was approved by the Review Board of our hospital. The inclusion criteria were as follows: 1) a one-level thoracolumbar fracture (T10-L2), and Thoracolumbar Injury Classification and Severity Score (TLICS) ≥ 4; 2) a lack of neurological deficits and Grade E American Spinal Injury Association (ASIA) classification; 3) the application of the Wiltse paraspinal approach or O-arm navigation as the minimally invasive technique for treating injuries lasting less than one week; 4) age between 20 and 65 years; and 5) a follow-up duration of more than 12 months. The exclusion criteria were as follows: 1) pedicle fracture, multilevel fracture, pathologic fracture, or severe osteoporotic fracture (bone mineral density (BMD) t score <-2.5); 2) previous surgery at the fracture site; 3) other injuries requiring surgery; and 4) other diseases, such as infection, tumor, metabolic disease, etc.

Fifty-four patients with single-segment, neurologically intact thoracolumbar fractures (T10–L2) who met the aforementioned criteria were enrolled in this study. The patients were divided into two groups based on the minimally invasive surgery performed. Twenty-eight patients who underwent pedicle screw fixation through the mini-open Wiltse paraspinal approach were classified as group A (WPSF), and 26 patients who underwent percutaneous screw placement with the O-arm-based navigation system served as group B (OPSF) (Fig. 1). Group A included 22 males and 6 females, and the mean age was 48.6±9.6 (range 33~63 years). One patient had a facture in T10, 2 in T11, 8 in T12, 10 in L1 and 7 in L2. Group B included 15 males and 11 females, and the mean age was 45.7±10.6 (range 29~63 years). One patient had a fracture in T11, 6 in T12, 10 in L1 and 9 in L2. The demographic data of the two groups are shown in Table 1.

Minimally invasive techniques

WPSF group

The patient was placed in a prone position after the administration of general anesthesia. The injured vertebral body was located and labeled under fluoroscopic guidance of C-arm (Ziehm Imaging, Nuremberg, Germany). The surgeon made a midline incision of approximately 8cm at the operative region following routine sterilization and draping. The skin, subcutaneous tissue and lumbodorsal fascia were cut successively and the gap between the longissimus and multifidus muscles was separated bluntly to expose the entry point of the nail path. After the appropriate drilling and probing, six pedicle screws were installed sequentially by hand with the aid of C-Arm fluoroscopy, used to determine optimal locations for the pedicle screws. After the two connecting rods were implanted, the screws were tightened to reposition the anterior column of the vertebral body. The position of the internal fixation and restoration of the fracture centrum were again examined by radiology.

OPSF group

After satisfactory tracheal intubation and general anesthesia, the patient was placed in a prone position on a Jackson radiolucent table, and the surgical site was sterilized and draped. A reference frame was installed on the spinous process following the removal of the peripheral soft tissue. The O-arm (Medtronic, CO, USA) performed a first scan to acquire an intraoperative 3D image and the radiological data was transferred to a StealthStation navigation system (Medtronic, CO, USA). The surgeon moved the passive planar probe to confirm the entry point of the stab incision, guided by the 3D image navigation system. A hole for the guide wire was drilled, the guide wire was inserted, and the pedicle screws were tapped and implanted without any manual regulation. The screws were adjusted for the direction and length through the images provided by the navigation equipment, to construct the optimal trajectory. The connecting rods were prebent properly and then inserted percutaneously. The tailcaps of the distal vertebral screws and those in the injured vertebra were tightened along the connecting rods, and then the height of the fracture vertebra was restored by stretching. Finally, the tailcaps of the proximal screws were tightened. The O-arm performed another scan to confirm the correct position of the internal fixation.

The incision was rinsed and closed with interrupted suturing. No drainage tube was inserted for either groups. All patients underwent routine prophylactic antibiotics for 2 days and were instructed to stand while wearing a brace on the third day after surgery.

Clinical evaluation

The clinical indicators examined included operative time, intraoperative blood loss, total length of incision, postoperative hospitalization time and operation expenditure. We appraised the efficacy of the procedure by using the visual analog scale (VAS) scores, calculated on a scale of 0–10 preoperatively, postoperatively and at final follow-up. The Oswestry disability index (ODI) scores were also evaluated on a scale of 0%–100% preoperatively and at final follow-up. All patients in both groups completed the survey independently, without receiving any suggestions during the investigation. All patients of the two groups were received a follow-up period for at least 12 months independently, and complications were recorded.

Radiologic assessment

The radiological outcomes were measured preoperatively and at 3 days and 12 months after the operation. The local Cobb angle (LCA), which reflected the changes in segmental kyphosis, was assessed between the superior endplate of the upper adjacent vertebra and the inferior endplate of the lower adjacent vertebra. The vertebral wedge angle (VWA) was measured between the superior endplate and the inferior endplate of the fractured centrum [12]. The ratio of the anterior margin height of the fractured vertebra (R value) was determined as described by Li et al [5]. The correction value was the preoperative value minus the immediate postoperative value, and the correction loss value was the final follow-up value minus the immediate postoperative value. The accuracy of pedicle screw placement was assessed using coronal and axial reformatted CT images. The position of the pedicle screw was considered to be misplaced when it was extrapedicular or had broken through the anterior edge, cephalad and caudal endplates of the vertebral body [5]. The radiographic data were collected by an experienced radiologist who had no knowledge of this study with the software of picture archiving and communication system (PACS, Neusoft, Shenyang, China). The specific details and measuring methods are shown in Figure 2.

Statistical analysis

Continuous variables such as operation time, blood loss, length of incision, LCA and VWA are presented as mean ± standard deviation (SD). Categorical variables such as gender, fracture site and classification are expressed as numbers or percentages. Statistical methods for comparision the two groups included Student's *t* test and c^2 or Fisher's exact test. A *p* value of less than 0.05 was regarded as statistically significant . All the data were statistical analyzed using SPSS 19.0 statistical software (SPSS Inc., Chicago, IL, USA).

Results

There were no significant differences in age, gender, injured segment, fracture type, blood loss, length of incision or postoperative hospitalization time between the two groups (p>0.05, Table 1). All patients underwent surgery successfully, and no serious complications, such as infection, blood vessel injury, or spinal cord or nerve root injury occurred. All patients experienced a mean follow-up duration of 16.1±2.6 months (12~20 months) in group A (Fig. 3) and 16.0±2.5 months (12~20 months) in group B (Fig. 4), with no significant difference between the groups (p=0.84). During the follow-up period, no patients developed neurological impairment or implant-related complications, and no patients underwent revision surgery.

Clinical outcomes

The mean operation time was 68.1±9.8 minutes (48~88 minutes) in group A and 76.1±9.0 minutes (60~95 minutes) in group B, which showed significantly difference (p<0.01, Table 1). The operative costs for group A were 48142.1±1430.1 CNY, which were significantly lower than those of group B (59035.4±1152.7 CNY, p<0.01, Table 1). The VAS scores were reduced pronouncedly from 6.5±1.2 preoperatively to 2.2±0.9 postoperatively, and to 0.4±0.5 at the last follow-up in group A (p<0.05, Table 2).

A similar trend from 6.7±1.2 preoperatively to 2.1±0.8 postoperatively and to 0.3±0.5 at the last follow-up, was observed in group B ($p<0.05$). There was no clear discrepancy regarding the VAS scores between the groups at each time point ($p>0.05$). The ODI scores decreased significantly from 92.9±4.3% preoperatively to 3.1±2.2% at the last follow-up in group A and from 93.3±4.4% preoperatively to 2.8±2.0% at the last follow-up in group B ($p<0.05$, Table 2). However, these was no significant difference regarding ODI scores between the groups preoperatively and at the last follow-up ($p>0.05$).

Radiologic outcomes

The accuracy of pedicle screw placement was 97.6% (164/168) in group A and 96.8% (151/156) in group B, with no significant difference between the groups ($p=0.63$). The LCA in both groups was markedly decreased after surgery, and these were well maintained at the last follow-up ($p<0.05$, Table 3). There was no significant difference regarding LCA between the two groups at either time point ($p>0.05$). The correction and loss of LCA in group A were 6.9±6.2° and 1.8±2.9°, respectively, while those in group B were 6.8±5.6° and 1.5±2.7°, respectively, which showed no apparent differences between the groups ($p>0.05$).

The average preoperative VWA was reduced significantly after surgery in both groups, and these values were well preserved until the final follow-up ($p<0.05$, Table 3). There was no significant difference regarding the VWA between the two groups at each time point ($p>0.05$). The correction and loss of VWA in group A were 8.4±4.6 and 0.7±1.8°, respectively, while those in group B were 8.1±4.5 and 0.2±2.7°, respectively, which showed no significant differences between the groups ($p>0.05$).

Postoperatively, the R values had all increased pronouncedly, from 72.4% in group A and from 74.0% in group B to 99.9% ($p<0.05$, Table 3). At the final follow-up, the R values were 97.4% in group A and 97.2% in group B. There was no clear difference in the R value between the groups at each time point ($p>0.05$). The correction and loss of the R value showed no significant differences between the groups ($p>0.05$).

Discussion

Posterior open surgery is one of the most common surgical methods for the treatment of thoracolumbar fractures [6]. There are several ineluctable drawbacks in conventional open posterior pedicle screw fixation. The muscles along the spine are stripped from the bone portion of the spine, exposing the facets and transverse processes to position the screws accurately. This could lead to complications associated with the surgical approach, including excessive intraoperative bleeding, intramuscular loss of innervation and ischemia, and even long-term muscle atrophy and scarring, which are related to intractable back muscle pain and dysfunction [3]. Anatomically, the posterior muscles and ligaments of the thoracolumbar spine play an important role in maintaining stability. Therefore, these muscles and ligaments should be well preserved in operations of thoracolumbar vertebral fractures [5].

In recent years, minimally invasive surgery has developed rapidly, broadening the surgical indications for thoracolumbar fractures without neurological symptoms. The placement of the pedicle screws by minimally invasive techniques does not require the stripping of paravertebral muscles and ligament tissue, thus reducing the incidence of approach-related complications. Multiple studies have demonstrated the advantages of minimally invasive nailing techniques, including reduced pain, less soft tissue injury, shorter hospitalization times, and rapid rehabilitation [3,5-10].

In 1968, Wiltse et al. [13] first proposed a paraspinal muscle approach between the multifidus and longissimus, which retained the integrity of the posterior ligament complex and could produce less bleeding and surgical trauma compared with the traditional open approach. Li et al. [5] found that the Wiltse approach had obvious advantages over the conventional open method in terms of operative time, blood loss, postoperative drainage, postoperative hospitalization time, and postoperative improvement in the VAS score. Liu et al. [7] reported that the multifidus cross-sectional area decreased by only 7.6% in the Wiltse group compared to 35.4% in the posterior open group between pre-op and the last follow-up. This suggests that the Wiltse approach results in a lower incidence of multifidus atrophy and fatty infiltration, making it effective as a minimally invasive approach for thoracolumbar fracture.

In recent years, various fluoroscopic-based navigation systems have been introduced that provide information on the elaborate bony anatomy and have been clinically evaluated [14-18]. The O-arm system is an intraoperative imaging platform that combined with the Stealth Station navigation system that can be used to increase the accuracy of pedicle screw placement. Compared to traditional C-arm fluoroscopy, O-arm-based navigation has several advantages, such as high-quality multidimensional image, lager surgical fields, and robotic positioning [16,17]. Van et al. [18] performed a prospective multicenter clinical registry of thoracic, lumbar, and sacral pedicle screw placement using O-arm navigation to assess the accuracy of screw placement. They evaluated a total of 1922 screws in 353 patients, and found that only 2.5% of the screws were misplaced. Silbermann et al. [16] assessed the accuracy of pedicle screw placement in the lumbar-sacral spine between a free-hand technique and O-arm-based navigation method. The results indicated an accuracy rate of 99 % in the O-arm group compared to 94.1 % in the free-hand group.

Compared with those of open surgery, minimally invasive treatment with the Wiltse approach or O-arm 3D imaging for the treatment of thoracolumbar fractures can provide less tissue trauma and bleeding, shorter operation and hospitalization times, and more accurate placement of pedicle screws [5-7,9,17,18]. However, comparisons of the clinical effects and radiological results between the two minimally invasive techniques have not been reported in the literature. In this study, there were no significant differences in intraoperative blood loss, length of incision, or postoperative hospital stay between the two groups. The VAS scores and ODI scores obtained after application of the two minimally invasive techniques were significantly lower than the corresponding preoperative scores, and no difference was found between the groups. Therefore, we believe that the two minimally invasive nailing methods can achieve the same therapeutic effect for thoracolumbar fractures. Regarding operative time, the paravertebral approach group showed markedly shorter values than the O-arm navigation group, possibly because the placement and operation of the O-arm imaging system is more time consuming and the surgeon was unfamiliar with the relevant special instruments. In addition, we also compared the surgical cost expenditures of the two groups and found expectedly higher costs in the OPSF group (59,035.4±1,152.7 CNY) compared to the WPSF group (48,142.1±1,430.1 CNY). The principal reason for the cost difference is that more expensive implants and intraoperative neurophysiological monitoring were used in the O-arm navigation group.

The accuracy of screw position was 97.6% (164/168) in the WPSF group and 96.8% (151/156) in the OPSF group. There were no complications caused by misplacement during follow-up. The results showed better accuracy in the paravertebral approach group, although no significant difference was found. We reasoned that placement of the pedicle screws through the Wiltse approach provide relatively intuitive vision. In this study, we used short-segment fixation with six pedicle screw combined with intermediate screw fixation in both groups. Most authors reported that short-segment instrumentation with four pedicle screws was not adequate to achieve and maintain the reduction of thoracolumbar fractures and was associated with an unacceptable rate of failure [19,20]. Compared to conventional 4-screw intersegmental fixation, short-segmental fixation combined with intermediate screws enhanced the strength of the fixation, which could be helpful for maintaining the reduction in the height and angle of the fractured vertebra, and allowed much earlier ambulation, which is important for recovery and avoiding complications [21]. In the current study, the Cobb angle and VWA showed significant differences between pre-op and post-op in both groups. The average postoperative R values of the two groups were all 99.9%, which means that both minimally invasive techniques could basically reset the fractured vertebra to their physiological height. Moreover, no distinct increase was observed in the Cobb angle and VWA between post-op and final follow-up in either groups. The correction loss of the R value was only 2.5% in the WPSF group and 2.7% in the OPSF group, with no clear discrepancy between groups. These results indicate that the two minimally invasive techniques have satisfactory effects on the correction of kyphosis and preservation of segment height.

There are also some limitations in the current research. First, the study was retrospective, and the treatment options for the recruited patients mainly depended on their preference, which implied a lack of randomization. However, there were no significant differences in the preoperative clinical and X-ray data between the two groups. Second, only 54 patients were ultimately included in this study; thus the conclusions drawn from the statistics lack sufficient power. Third, the follow-up duration in the study was relatively short. An extended observation period should be implemented to better evaluate clinical efficacy, aggravated kyphosis, and the failure of fixation. In the future, randomized controlled trials and additional assessment methods could confirm the results of our study.

Conclusion

The results of our research revealed that two minimally invasive techniques, the Wiltse paraspinal approach and percutaneous screw placement under O-arm navigation, both had excellent clinical efficacy for thoracolumbar fractures and did not lead to the emergence of troublesome complications. With treatment from the minimally invasive methods, patients in both groups achieved satisfactory outcomes, and kyphosis angle and anterior vertebral column were rectified and maintained until the last follow-up.

Nevertheless, the WPSF also provided a lower duration of surgery and surgical cost expenditures compared to the OPSF. In the current study, we concluded that WPSF could be the better choice for thoracolumbar fractures.

Abbreviations

WPSF: Pedicle screw fixation through Wiltse paraspinal approach;

OPSF: Pedicle screws fixation under O-arm navigation;

VAS: Visual analog scale;

ODI: Oswestry disability index;

LCA: Local Cobb angle;

VWA: Vertebral wedge angle;

R value: Ratio of anterior margin height of fractured vertebra;

ERAS: Enhancing Recovery After Surgery;

TLICS: Thoracolumbar Injury Classification and Severity Score;

ASIA: American Spinal Injury Association;

BMD: Bone mineral density;

PACS: Picture archiving and communication system;

WMD: Weighted mean difference;

SD: Standard deviation

Declarations

Ethics approval and consent to participate

This study is a retrospective clinical study and has been approved by The First Affiliated Hospital of Soochow University Ethics Committee. All patients had signed the consent form.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Concept, literature search and data collection: YJL, TFZ, XSZ, MFG.

Statistics, data analysis and interpretation: YJL, XS, YPF, DDL, LYZ.

Drafting article: YJL, TFZ.

Critical revision of article: XSZ, MFG.

All authors read and approved the final manuscript.

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Tables

	Group A	Group B	*p* values
Age (years)	48.6 ± 9.6	45.7 ± 10.6	0.31
Gender (male/female)	22/6	15/11	0.10
Fracture site (T10/T11/T12/L1/L2)	1/2/8/10/7	0/1/6/10/9	0.77
Fracture type (A1/A2/A3/B1)	12/1/9/6	14/0/8/4	0.67
Blood loss (ml)	38.8 ± 12.2	36.0 ± 10.7	0.39
Operation time (min)	68.1 ± 9.8	76.1 ± 9.0	< 0.01
Length of incision(cm)	7.9 ± 0.2	8.0 ± 0.3	0.09
Hospital stay(days)	4.2 ± 0.9	4.0 ± 0.9	0.57
Operative costs(CNY)	48142.1 ± 1430.1	59035.4 ± 1152.7	< 0.01
Follow-up (months)	16.1 ± 2.6	16.0 ± 2.5	0.84

Table 1

Demographic data of patients.

		Group A	Group B	*p* values
VAS	pre-op	6.5±1.2	6.7±1.2	0.48
	post-op	2.2±0.9*	2.1±0.8*	0.69
	last	0.4±0.5*	0.3±0.5*	0.73
ODI (%)	pre-op	92.9±4.3	93.3±4.4	0.73
	last	3.1±2.2*	2.8±2.0*	0.61

VAS visual analog scale, *ODI* Oswestry disability index

* p<0.05 Statistical significance compared to preoperatively

Table 2

Clinical data of VAS and ODI score.

		Group A	Group B	*p* values
LCA (°)	Pre-op	11.2 ± 10.6	10.5 ± 7.2	0.80
	Post-op	4.3 ± 9.4*	3.7 ± 6.2*	0.80
	Last	6.1 ± 10.3*	5.2 ± 7.6*	0.74
	Correction	6.9 ± 6.2	6.8 ± 5.6	0.96
	Loss	1.8 ± 2.9	1.5 ± 2.7	0.71
VWA (°)	Pre-op	12.9 ± 5.8	13.3 ± 5.4	0.77
	Post-op	4.5 ± 4.0*	5.2 ± 3.6*	0.47
	Last	5.1 ± 4.1*	5.5 ± 3.7*	0.77
	Correction	8.4 ± 4.6	8.1 ± 4.5	0.80
	Loss	0.7 ± 1.8	0.2 ± 2.7	0.48
R value (%)	Pre-op	72.4 ± 10.7	74.0 ± 11.0	0.59
	Post-op	99.9 ± 9.1*	99.9 ± 7.5*	0.99
	Last	97.4 ± 9.0*	97.2 ± 8.3*	0.93
	Correction	27.5 ± 14.8	25.8 ± 11.7	0.66
	Loss	2.5 ± 5.3	2.7 ± 4.2	0.87
Accuracy (%)		97.6 (164/168)	96.8 (151/156)	0.63

LCA Local Cobb angle, *VWA* vertebral wedge angle, *R value* Ratio of anterior margin height of fractured vertebra, *Correction* Pre-op value minus post-op value, *Loss* Last value minus post-op value

* $p < 0.05$ Statistical significance compared to preoperatively

Table 3

Radiological data of LCA, VWA, R value, and accuracy of pedicle screw placement.

Figures

Figure 1

Set up O-arm and navigation system during the procedure.

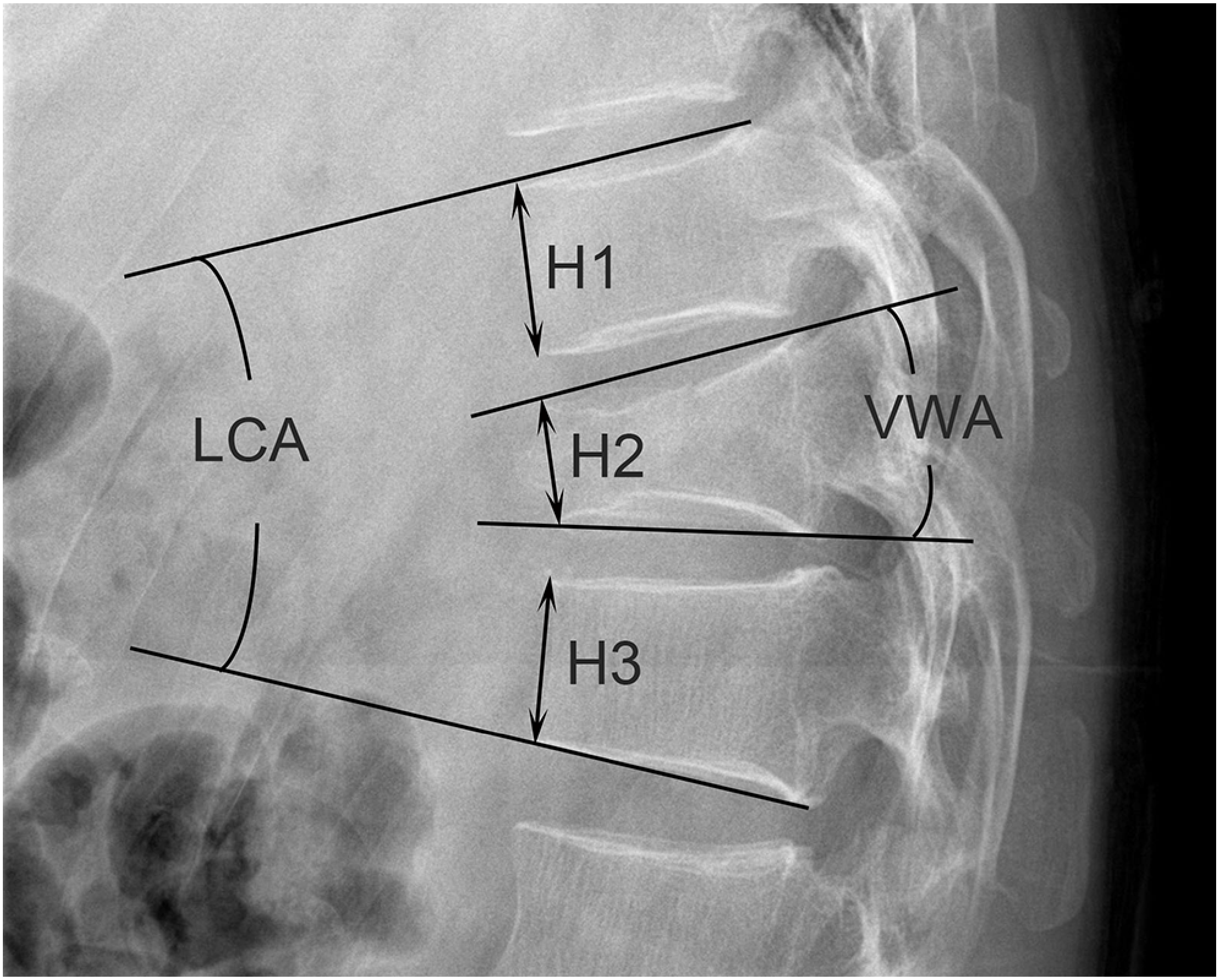

Figure 2

Measurement and collection of radiologic data on X-ray lateral film. LCA, Local Cobb angle; VWA, vertebral wedge angle; H1, Height of anterior edge of superior adjacent vertebra; H2, Height of anterior margin of fractured vertebra; H3, Height of anterior edge of inferior adjacent vertebra; The ratio of anterior margin height of fractured vertebra (R value) = [H2×2/(H1+H3)]×100%

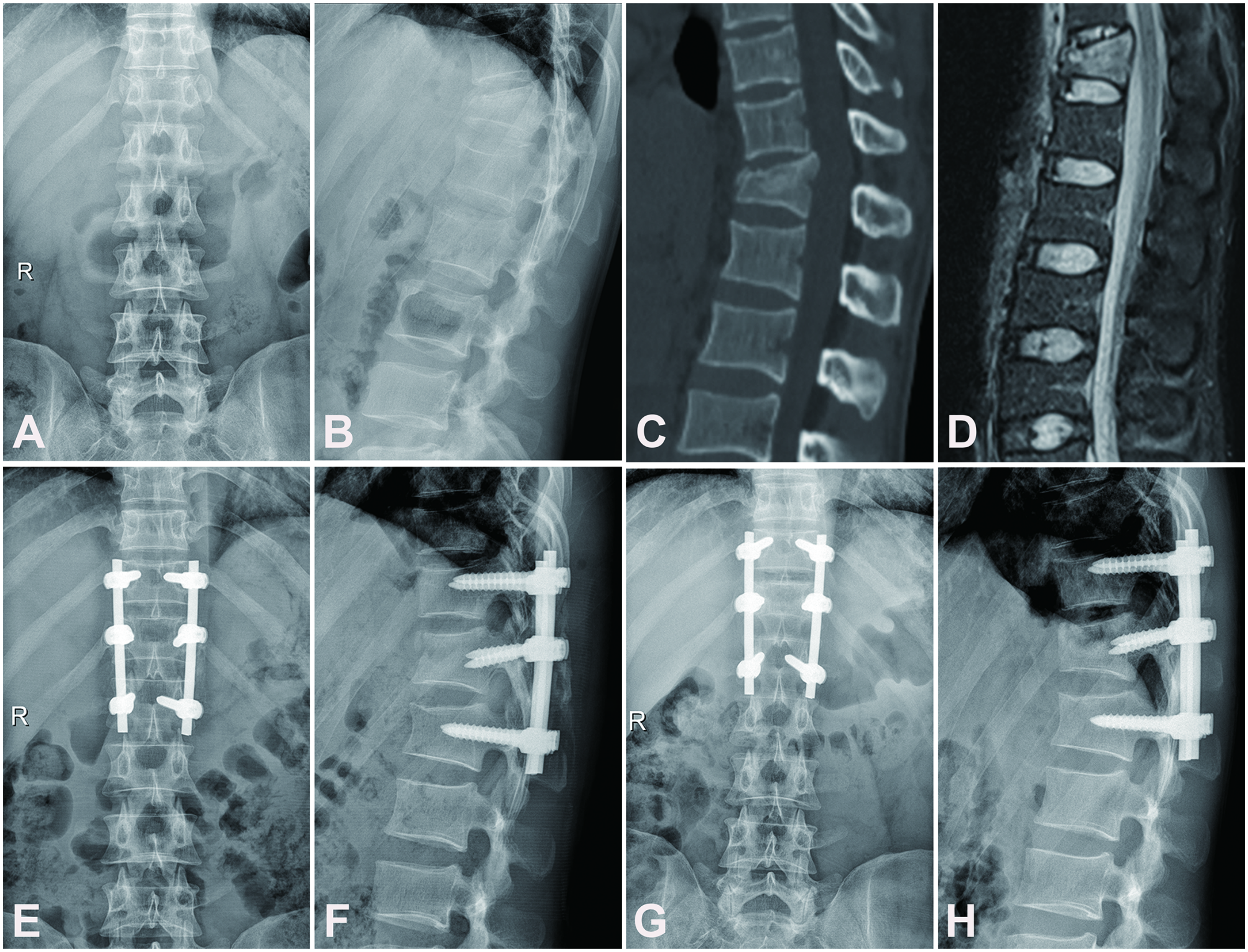

Figure 3

A 33-year-old male was treated with minimally invasive surgery through Wiltse paraspinal approach due to compression fracture of L2 (AO type A1). Preoperative imaging examination of anteroposterior (A) and lateral (B) X-ray radiographs, reconstructed sagittal CT scan (C) and sagittal plane of STIR sequence in MRI (D). Postoperative images of anteroposterior (E) and lateral (F). Final follow-up views of anteroposterior (G) and lateral (H).

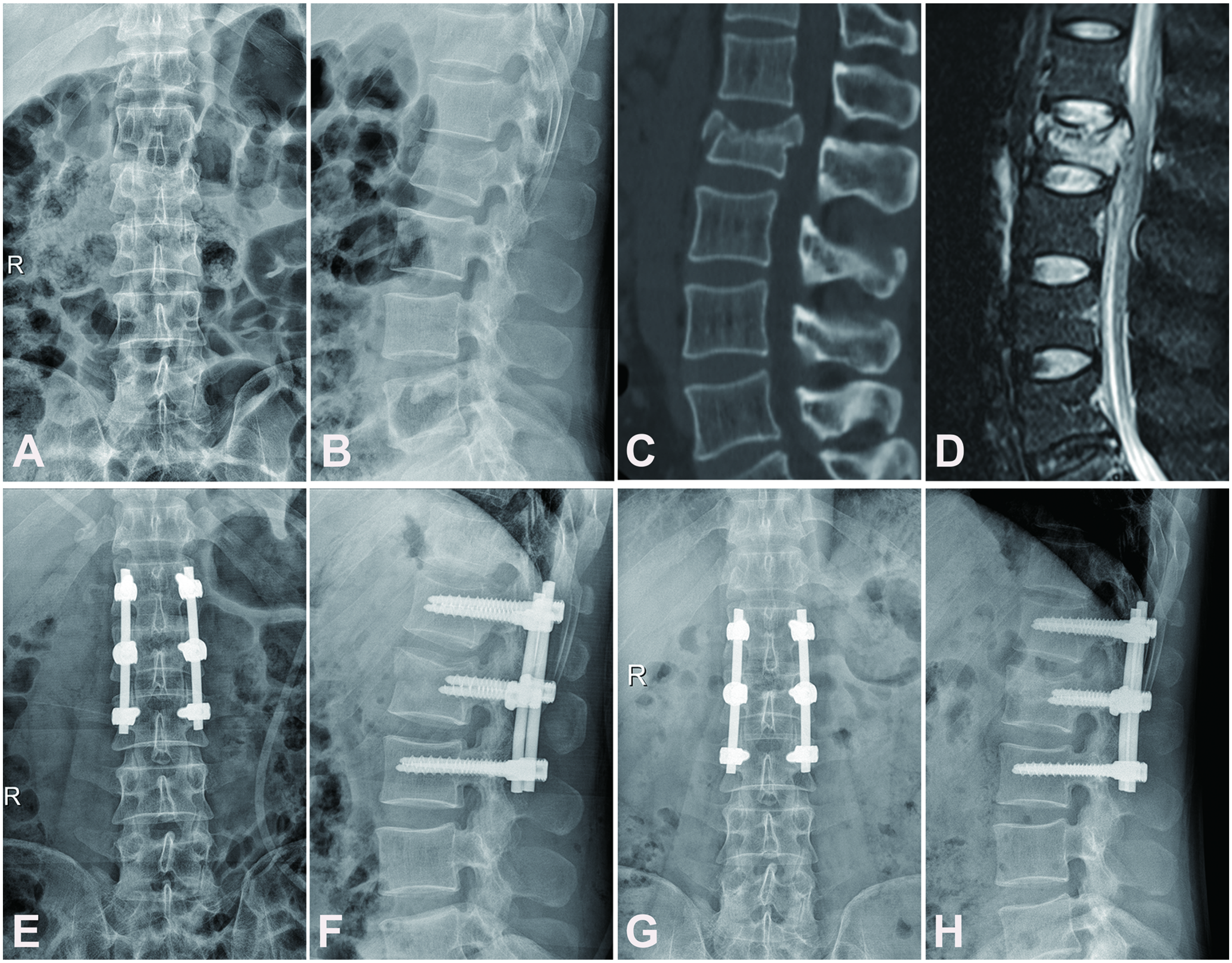

Figure 4

A 35-year-old male was received percutaneous pedicle screws fixation under O-arm navigation due to burst fracture of T12 (AO type A3). Preoperative imaging examination of anteroposterior (A) and lateral (B) X-ray radiographs, reconstructed sagittal CT scan (C) and sagittal plane of STIR sequence in MRI (D). Postoperative images of anteroposterior (E) and lateral (F). Final follow-up views of anteroposterior (G) and lateral (H).