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

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Research article

Keywords: Spinal fractures, Minimally invasive, Thoracolumbar, Wiltse approach, O-arm navigation

Posted Date: January 9th, 2020

DOI: https://doi.org/10.21203/rs.2.20472/v1

Abstract

Background

To evaluate the clinical efficacy of 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 that received minimally invasive technology. Among these, 28 cases were treated with pedicle screw fixation through Wiltse paraspinal approach (WPSF), and another 26 cases were received percutaneous pedicle screws fixation under O-arm navigation (OPSF). The statistical methods were used to performing a detailed comparison of clinical outcomes, radiologic findings and complications between the two groups at pre-op, post-op and last follow-up.

Results There were no significant differences between the two groups among intraoperative bleeding, length of incision, postoperative hospitalization times and 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 obviously improved after surgery, though no clear discrepancy between the groups at each time point ($p>0.05$). However, the OPSF group had longer operation time and higher 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 till the final follow-up, we recommended the minimally invasive technology of WPSF considering the lower duration of surgery and medical costs. A randomized controlled study of high-quality and large sample required to prove our findings in the future.

Introduction

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

With the tremendous development of minimally invasive technology, such as paraspinal muscular approach through Wiltse space, percutaneous pedicle screw placement under fluoroscopy, and O-arm (Medtronic, CO, USA) combined with navigation system (StealthStation, Medtronic, CO, USA) for the implantation of pedicle screw (Fig. 1), the aforementioned approach-related complications were evidently reduced. Meanwhile, the patient could achieve a smaller incision, rapidly reduced pain, shorter hospitalization stay, and return quickly to life and work [3, 5–10]. These had fully abided by the concept of Enhancing Recovery After Surgery (ERAS) in orthopedics [11].

Nevertheless, for many minimally invasive techniques, we required to grasp 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 the thoracolumbar burst fracture, and found that both surgical methods are safe and reliable, and finally they preferred Wiltse approach as a better choice while considering radiation exposure, operative cost, learning curve and reduction of kyphosis. In this study, we first performed a comparsion of Wiltse approach and percutaneous pedicle screw fixation under O-arm navigation for the treatment of thoracolumbar fracture, to study which minimally invasive technology was more beneficial for patients.

Materials And Methods

Patient population

Patients with a 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 was complied with the Declaration of Helsinki and was approved by the Review Board of our hospital. The inclusion criteria were as follows: 1) the type of injured vertebral body was one-level thoracolumbar fracture (T10-L2), and TLICS score ≥ 4; 2) no neurological deficits were present, and the classification of ASIA was Grade E; 3) all patients underwent minimally invasive technique with Wiltse paraspinal approach or O-arm navigation after being injured less than one week; 4) the patients ranged in age from 20 to 65 years; and 5) the follow-up duration was longer than 12 months. The exclusion criteria were as follows: 1) pedicle fracture, multi-level fracture, pathologic fracture, or severe osteoporotic fracture (bone mineral density (BMD) t score < -2.5); 2) previous surgery had been performed on the fracture site; 3) with other injuries requiring surgery; and 4) patients presented with other diseases, such as infection, tumor, metabolic disease and etc.

Fifty-four patients of 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 different types of minimally invasive surgery. 28 patients who underwent pedicle screw fixation through mini-open Wiltse paraspinal approach were classified as group A (WPSF), and 26 patients underwent percutaneous screw placement using O-arm-based navigation system served as group B (OPSF). Group A included 22 males and 6 females, and the mean age was 48.6 ± 9.6 (range 33 ~ 63 years). One patient was 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 was in T11, 6 in T12, 10 in L1, 9 in L2. The demographic data of the two groups are shown in Table 1.

Table 1
Demographic data of patients.

	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

Minimally invasive techniques

WPSF group

Patient was placed in a prone position after 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 about 8 cm on the operative region following routine sterilization and draping. Cut the skin, subcutaneous tissue and lumbodorsal fascia successively, then separated the gap between longissimus and multifidus muscles bluntly to expose the entry point of nail path. Six pedicle screws were drilled, probed and installed sequentially by bare-handed with the aid of C-Arm fluoroscopy, to pursue an optimal location of the pedicle screw. After the two connecting rods were implanted, then the screws were tightened to reposition the anterior column of the vertebral body. The position of internal fixation and restoration of fracture centrum were examined by radiology again.

OPSF group

After satisfactory tracheal intubating and general anesthesia, patient was positioned prone on the Jackson radiolucent table and finished steriling and draping. A reference frame was installed on a spinous process following the removal of the peripheral soft tissue. The O-arm entered the first scan to acquire the intraoperative 3D image and transferred the radiological data to the StealthStation navigation system. The surgeon moved passive planar probe to confirm the entry point of the stab incision with the guiding of 3D image navigation system. Drilling and inserting the guide wire, then tapping and implanting the pedicle screw 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 pre-bent properly and then penetrated percutaneously. The tail-caps of the injured and distal vertebral screws were tightened along the connecting rods then the height of the fracture vertebra was restored by stretching, and finally tightened the tail-caps of the proximal screws. The O-arm was scanned again to confirm the correct position of the internal fixation.

The incision was rinsed and closed with interrupted suturing. No drainage tube was inserted of the two groups. All patients underwent routine prophylactic antibiotics for 2 days, and were informed to get up with the brace wearing on the third day after surgery.

Clinical evaluation

The clinical indicators required to be examined that included operative time, intraoperative blood loss, total length of incision, post-operative hospitalization time and operation expenditure. We appraised the efficacy by using visual analog scale (VAS) scores as detailed as possible in the preoperative, postoperative and final follow-up. Oswestry disability index (ODI) scores were also evaluated at pre-operation and final follow-up. All patients in the two groups completed the survey independently, without any given suggestions during the investigation. All patients of the two groups were received a follow-up period for more than 12 months independently, and complications were recorded.

Radiologic assessment

The radiological outcomes were measured preoperatively and at 3 days and 12 months after operation. Local Cobb angle (LCA), which reflected the changes of segmental kyphosis, was described 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 anterior margin height of fractured vertebra (R value) was determined as described by Li et al [5]. Correction value was the preoperative value minus 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 break through the anterior edge, cephalad and caudal endplates of the vertebral body [5]. The radiographic data were collected by an experienced radiologist who has 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 Fig. 2.

Statistical analysis

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

Results

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

Clinical outcomes

The mean operation time was 68.1 ± 9.8 minutes (48 ~ 88 minutes) in the group A and 76.1 ± 9.0 minutes (60 ~ 95 minutes) in the group B, which showed significantly difference ($p < 0.01$, Table 1). The operative costs of the group A was 48142.1 ± 1430.1 CNY, which significantly lower than the group B of 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 0.4 ± 0.5 at last follow-up in group A ($p < 0.05$, Table 2). The similar trend was presented from 6.7 ± 1.2 preoperatively to 2.1 ± 0.8 postoperatively, and 0.3 ± 0.5 at last follow-up 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 were decreased significantly from 92.9 ± 4.3 preoperatively to 3.1 ± 2.2 at last follow-up in group A and from 93.3 ± 4.4 preoperatively to 2.8 ± 2.0 at last follow-up in group B ($p < 0.05$, Table 2). However, no statistical difference regarding ODI scores between the groups at pre-op and last follow-up ($p > 0.05$).

Table 2
Clinical data of VAS and ODI score.

		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

Radiologic outcomes

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

Table 3
Radiological data of LCA, VWA, R value, and accuracy of pedicle screw placement.

		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

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

At postoperatively, the R values were all increased pronouncedly from 72.4% in group A and from 74.0% in group B to 99.9% ($p < 0.05$, Table 3). Moreover, the R values were retained to 97.4% in group A and 97.2% in group B at the final follow-up. No clear discrepancy regarding 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 of the screws accurately. This could lead to complications associated with the surgical approach, including excessive intraoperative bleeding, intramuscular loss of innervation, swelling and ischemia, even long-term muscle atrophy and scarring, which related to intractable back muscle pain and dysfunction after surgery [3]. Anatomically, the posterior muscles and ligaments of the thoracolumbar spine play an important role in maintaining the stability of the corresponding segments. Therefore, these muscles and ligaments should be well preserved in the operation 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 screw 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 and intraoperative bleeding, shorter postoperative hospitalization times, and rapid rehabilitation [3, 5–10].

In 1968, Wiltse et al. [13] first proposed the conception of the paraspinal muscle approach between multifidus and longissimus, which retained the integrity of posterior ligament complex, could produce less bleeding and surgical trauma compared with traditional open approach. Li et al. [5] found that the Wiltse approach had obvious advantages over the conventional open method in operative time, blood loss, postoperative drainage, postoperative hospitalization time, and postoperative improvement in VAS. Wu et al. [14] also found operation duration, blood loss, average length of incision and postoperative ODI of the paraspinal group were all obviously less than the traditional posterior approach group. Liu et al. [7] reported 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 suggested that the Wiltse approach had a lower incidence of multifidus atrophy and fatty infiltration, so it was effective as a minimally invasive approach for thoracolumbar fracture.

In recent years, various fluoroscopic-based navigations have been introduced that provided the information of elaborate bony anatomy and experimented clinically [15–19]. The O-arm system is one of the intraoperative imaging platforms combined with Stealth Station navigation system that can be used to increase the accuracy of pedicle screw placement. Compared to traditional C-arm fluoroscope, the O-arm based navigation has several superiorities such as high quality of multi-dimensional images, lager filed of surgical view, and robotic positioning [17, 18]. Van et al. [19] performed a prospective multicenter clinical registry of thoracic, lumbar, and sacral pedicle screw placement using the O-arm navigation to assess the accuracy of screw placement. They evaluated a total of 1922 screws in 353 patients, and found only 2.5% of the screws were considered as misplaced. Silbermann et al. [17] assessed the accuracy of pedicle screw placement in lumbar-sacral spine between free-hand technique and O-arm based navigation method. The results noted that the accuracy rate was 99% in the O-arm group compared to 94.1% in the free-hand group.

Compared with the open surgery, the minimally invasive nailing with the Wiltse approach or O-arm 3D imaging for the treatment of thoracolumbar fractures have the advantages of less tissue trauma and bleeding, shorter operation and hospitalization time, and more accurate placement of pedicle screw [5–7, 9, 18, 19]. However, the comparison of clinical effect and radiological results between the two minimally invasive techniques has not been reported in the literature. In this study, there were no significant differences in intraoperative blood loss, length of incision, and postoperative hospital stay between the two groups. The VAS score and ODI score of the two minimally invasive techniques were significantly lower than the pre-op scores, and no distinction was drawn between the groups. Therefore, we believe that the two minimally invasive nailing methods can achieve the same therapeutic effect for thoracolumbar fractures. In aspects of operative time, the paravertebral approach group was obviously shorter than the O-arm navigation group, which possibly due to the fact that the placement and working of the O-arm imaging system is more time consuming and the surgeon is unfamiliar with the relevant special instruments. In addition, we also compared the surgical expenditure of the two groups, and showed expectable higher costs in OPSF group (59,035.4 ± 1,152.7 CNY) compared to WPSF group (48,142.1 ± 1,430.1 CNY). The principal reason for the cost difference was 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 was no complication caused by the misplacement during follow-up. The results showed a better precision in the paravertebral approach group, though no significant difference was found. We reasoned that the placement of pedicle screws through Wiltse approach provide relatively intuitive vision. In this study, we used short-segment six pedicle screw fixation combined with intermediate screw fixation in both groups. Most authors reported that short-segment instrumentation with four pedicle screw was not adequate to achieve and maintain the reduction of thoracolumbar fractures and were associated with an unacceptable rate of failure [20, 21]. Compared to conventional 4-screw inter-segmental fixation, short-segmental fixation combined with intermediate screws enhanced the strength of fixation, which is helpful for maintaining reduction of the height and angle of the fractured vertebra, and allowed much earlier ambulation, which is important for recovery and avoiding complications [22]. In the current study, the Cobb angle and VBA showed significant differences between pre-op and post-op in both groups. The average R values of the two groups were all restored to 99.9%, which means that both minimally invasive techniques can basically reset the fractured vertebra to the physiological height. Moreover, no distinct increase was presented in Cobb angle and VBA between post-op and final follow-up in both groups. The correction loss of R value was only 2.5% in the WPSF group and 2.7% in the OPSF group, respectively, with no clear discrepancy between groups. These indicate that the two minimally invasive techniques have satisfactory effects on the correction of kyphosis and preservation of segment height.

There also have some limitations in current research. First, the study was retrospective, and the treatment options of recruited patients mainly depend on their will, which implied non-randomized. Although there were no significant differences of preoperative clinical and X-ray data between the two groups. Second, the quantity of patients in this study was only 54 people, thus the conclusions drawn from statistics still not strong enough. Third, the follow-up duration of the study was relatively short. An extended observation should be needed for the evaluation of clinical efficacy, aggravated kyphosis, and the failure of fixation. In the future, the development of randomized controlled trials and more assessment methods will confirm the results of our study.

Conclusion

The results of our research revealed that the minimally invasive technology of Wiltse paraspinal approach and percutaneous screw placement under O-arm navigation for thoracolumbar fractures were both acquired excellent clinical efficacy without emergence of troublesome complications. With the help of two minimally invasive methods, patients of both groups achieved satisfactory outcomes, and kyphosis angle and anterior vertebral column were rectified and maintained till the last follow-up. Nevertheless, the WPSF also provided a lower duration of surgery and surgical expenditure compared to the OPSF according to statistical calculation. In current study, we had drawn a conclusion that WPSF could a 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;

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.

Funding

No funding.

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.

Acknowledgement

This work was supported by the National Natural Science Foundation of China (NSFC) under grant No. 81772358

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Figures

Figure 1

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

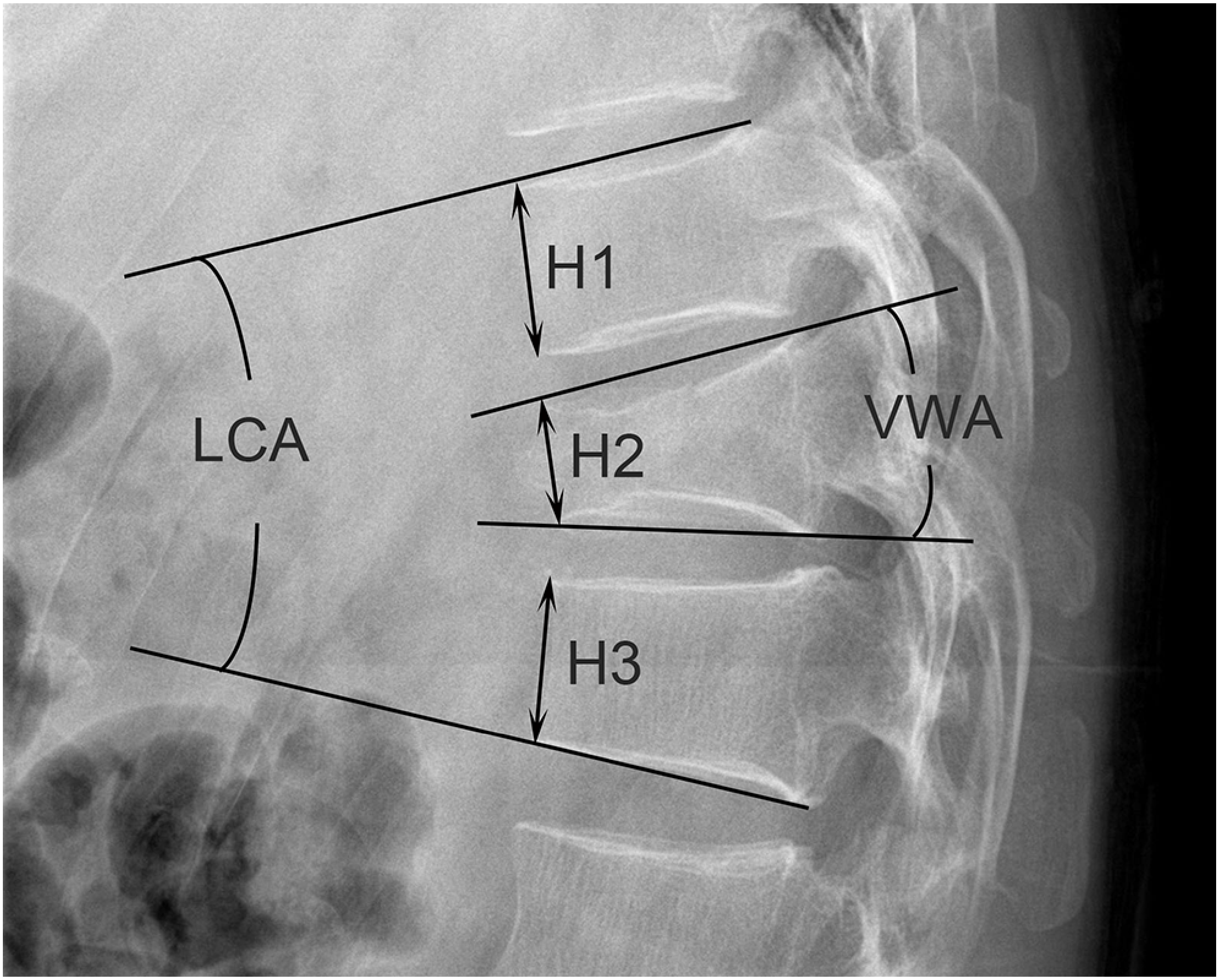

Figure 2

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%

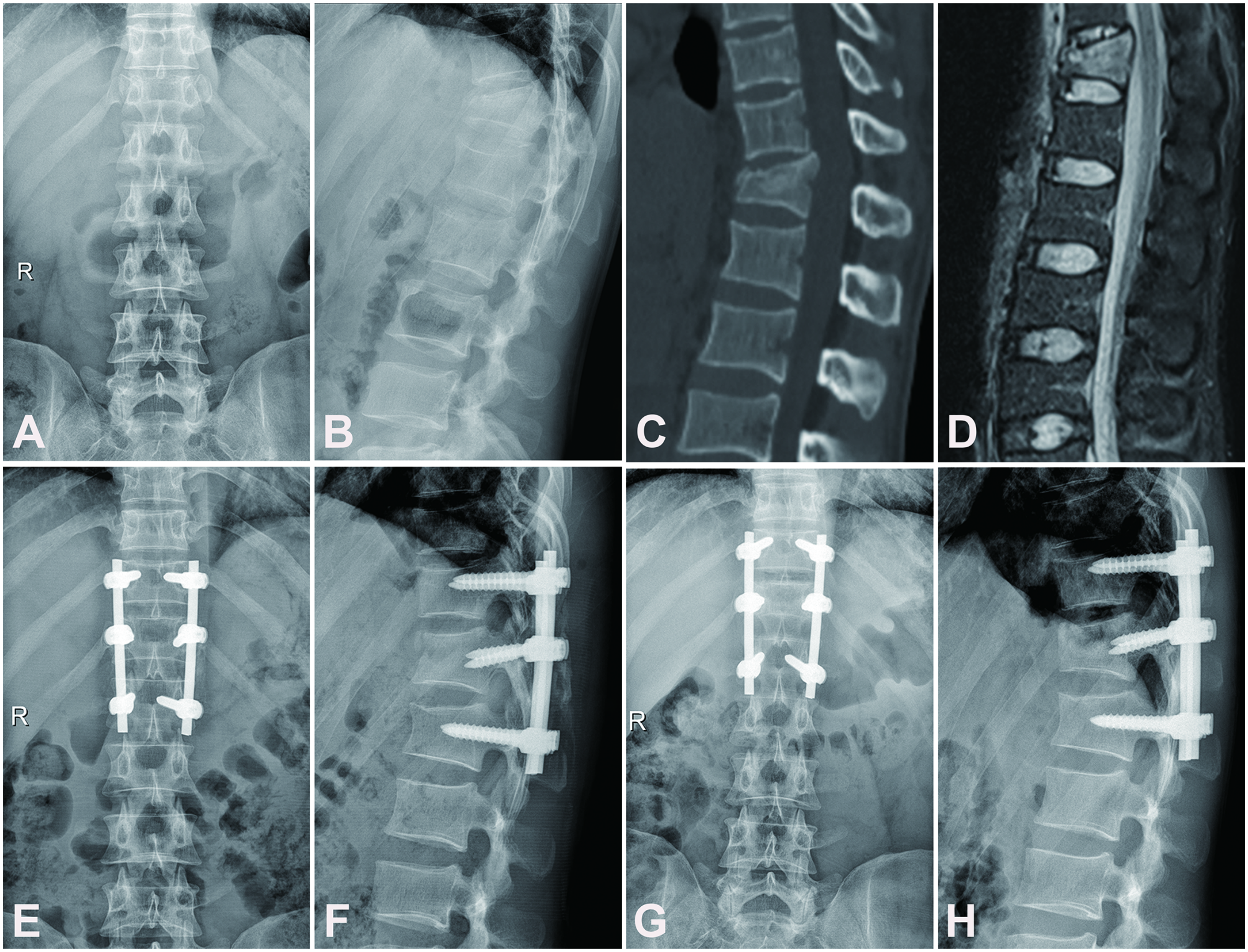

Figure 3

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).

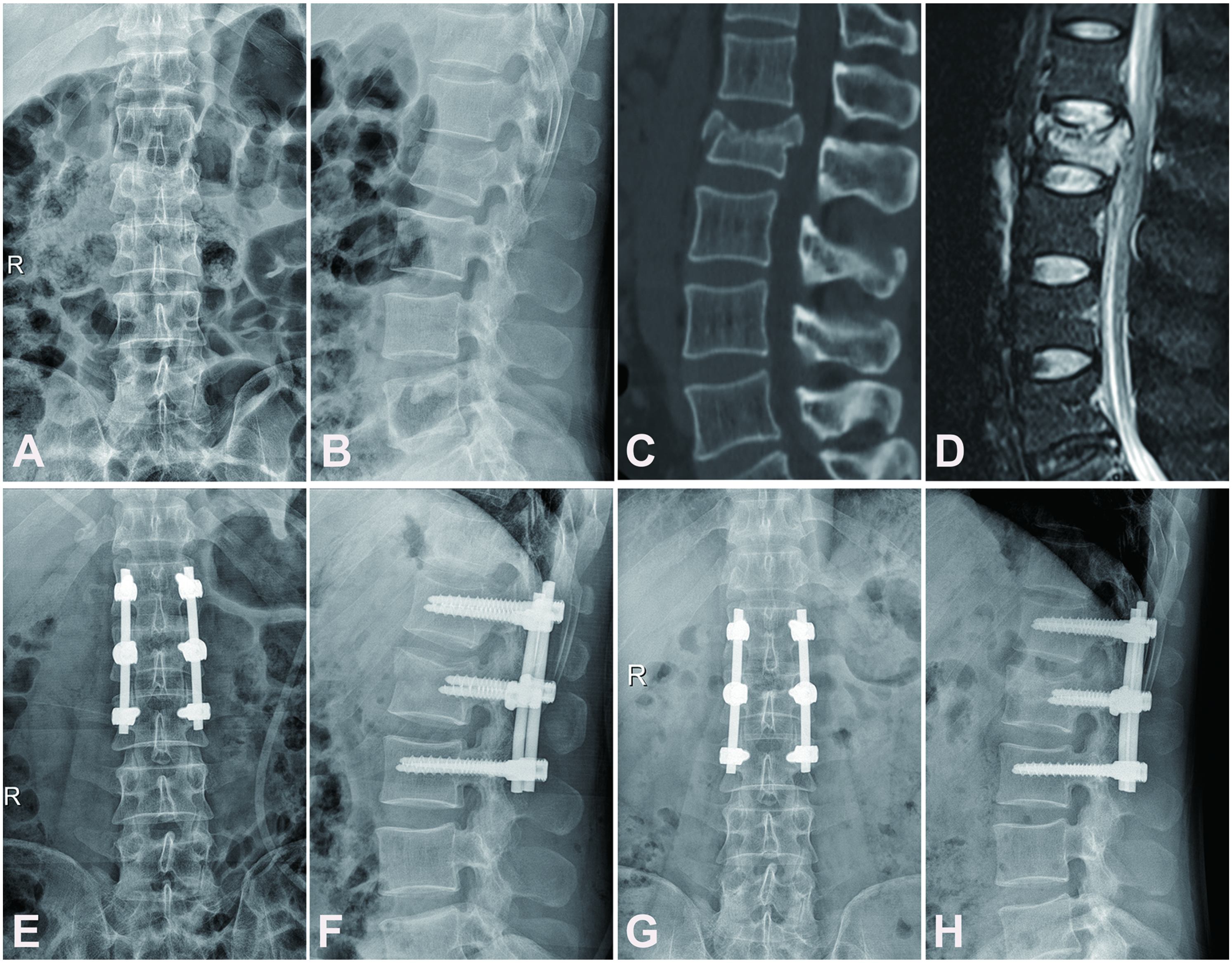

Figure 4

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).