Orthopaedic Surgery

CLINICAL ARTICLE

Novel Screw Insertion Method for Anterior Surgical Treatment of Unstable Thoracolumbar Fracture: Quadrant Positioning Method

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Objective: To develop a novel screw positioning method to improve the treatment of unstable thoracolumbar fractures.

Methods: A total of 72 patients with unstable thoracolumbar fractures who were treated with anterior screw–rod interfixation from January 2011 to October 2015 were included in this clinical study. Those patients included 48 male and 24 female patients with an average age of 45.10 years (range, 26–63 years). Patients were randomly divided into two groups: an observation group (n = 36) and a control group (n = 36). The quadrant positioning method was used for screw insertion in the observation group during the operation, while the traditional screw positioning method was used in the control group. The quadrant positioning method targeted four quadrants, including the superior anterior (SA), superior posterior (SP), inferior anterior (IA) and inferior posterior (IP) quadrants, while for the traditional screw positioning, four screws were inserted into the vertebral bodies above and below the excision. Patients were followed up for approximately 40 months to record recovery. Clinical and radiological records, local angle and fractured vertebra body height, clinical outcomes, complications, neurological improvement, and fusion rate were recorded and compared between the two groups.

Results: The quadrant positioning method was successfully used for anterior screw insertion. The quadrant center in the lateral view of the vertebral body was well marked, and screws were easily located on the scheduled quadrant. Blood loss (BL), hospital stay (HS), and operation time (OP) in the observation group were 749.40 ± 379.90 mL, 17.10 ± 4.10 days, and 167.40 ± 44.70 min, respectively. While those parameters in the control group were 1198.40 ± 339.27 mL, 23.22 ± 3.77 days, and 221.47 ± 32.15 min, respectively. The average operation time and hospital stay time were significantly shorter, and blood loss was significantly less in the observation group than in the control group ($P < 0.05$). Local angle and vertebral body height were markedly improved and 1–2 grade improvement was achieved in patients with neurological deficits in both groups. Both groups of patients achieved bony fusion during follow-up. No incision infection or internal fixation failure was observed in the two groups, and complications including cerebrospinal fluid and chylous leakage and hemothorax were resolved.

Conclusions: The quadrant positioning method can shorten operation time, reduce blood loss, and accelerate postoperative recovery. The technique provides an effective method for screw insertion for double screw–rod instrumentation fixation in the treatment of thoracolumbar fracture *via* the anterior approach.

Key words: Anterior approach; Quadrant method; Screw positioning; Thoracolumbar fracture

Introduction

The thoracolumbar junction is the junction between the thoracic and the lumbar spine, composed of T_{11}–L_2. Spinal curvature changes from kyphosis to lordosis at the thoracolumbar junction, and the change from coronal to sagittal also occurs at this junction. Due to the specific position

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and composition of the thoracolumbar junction, it is usually affected in spinal fractures[1]. More than 5 million patients are affected by vertebral fractures every year and more than 70% of all spinal fractures involve the lumbar and thoracic spine[1]. Thoracolumbar spine fractures are common injuries in clinical practice and typically lead to significant deformity, disability, as well as neurological deficit. Therefore, thoracolumbar spine fractures have become a heavy burden on public health. At present, there are no standards for the treatment of thoracolumbar spine fractures in regard to surgical management indications, appropriate radiological investigations, and the approach, timing and type of surgery[1]. Although the optimal strategy for the treatment of thoracolumbar fracture remains controversial, surgical treatment is recommended for unstable burst fractures or patients with neurological deficits[2,3].

Surgical treatment for thoracolumbar fractures mainly involves anterior, posterior, or combined approaches. Different approaches have different advantages and disadvantages, and decision-making is critical for successful surgery. At present, posterior approach surgery is most commonly used due to its advantages in relation to fracture reduction, spinal stability improvement, and low morbidity. However, progressive kyphosis, indirect decompression, and hardware failure remain concerns in the application of the posterior approach due to lack of anterior column support[4,5]. In contrast, the anterior approach may benefit medullary decompression by corporectomy and allow the reconstruction of the anterior column[6,7]. Treatment outcomes of thoracolumbar fractures are affected by many factors, and no consensus on the ideal approach has been reached. The anterior approach is well-described by Kanada *et al.*[8]; a series of following studies[6–10] report on detailed surgical techniques, therapeutic effects, and related complications. However, outcomes of anterior screw insertion, including positioning and direction, which are key points for anterior surgery, are still unsatisfactory. In view of the advantages and disadvantages of different types of positioning methods, it is reasonable to hypothesize that a positioning method that targets four sites, including superior anterior (SA), superior posterior (SP), inferior anterior (IA), and inferior posterior (IP), may result in better clinical efficacy. To our knowledge, no such positioning method has been reported.

In the present study, the quadrant positioning method was successfully performed for anterior screw insertion. The quadrant center in the lateral view of the vertebral body was well marked, and screws were easily located on the scheduled quadrant. Compared with the traditional positioning method, the quadrant method significantly improved the intraoperative parameters, such as blood loss (BL), hospital stay (HS), and operation time (OP). Local angle and vertebral body height were markedly improved and 1–2 grade improvement in patients with neurological deficits was achieved in patients who received both traditional positioning or quadrant method positioning. Both groups of patients achieved bony fusion during follow-up.

No incision infection or internal fixation failure was observed in the two groups, and complications including cerebrospinal fluid and chylous leakage and hemothorax were resolved. Therefore, the quadrant method can attain similar short-term and long-term local outcomes as well as neurological function improvements compared with the traditional method; at the same time, the technique can reduce blood loss, operation time, and hospital stay. Therefore, the quadrant positioning method can reduce the economic burden of patients and can be accepted by more patients compared with the traditional method. Therefore, use of the quadrant positioning method should be promoted in clinical practice.

This study aims to develop a quadrant positioning method for screw insertion in anterior thoracolumbar surgery. In addition, the technique attempts to provide an easy way to improve the accuracy of screw insertion, which may be used in various procedures, including surgery to treat unstable thoracolumbar fractures through the anterior approach.

In this study we focused on three major points: (i) the comparison of intra-surgical parameters between the quadrant positioning method and traditional methods, such as blood loss (BL) and operation time (OP); (ii) comparison of short-term and long-term local outcomes between the quadrant positioning method and traditional methods, such as the kyphotic angle (KA), the lateral angle (LA), and anterior vertebral body height (AH); and (iii) comparison of short-term and long-term neurological assessment scores between the quadrant positioning method and traditional methods.

Patients and Methods

Participants

A total of 72 patients with thoracolumbar fractures, who were treated with anterior surgery from January 2011 to October 2015, were included.

Inclusion criteria: (i) one unstable thoracolumbar fracture (T_{11}–L_2) with or without neurological deficits; (ii) fracture type A3 according to the AO/Magrel classification[11]; and (iii) a score between 6–9 according to load-sharing classification[12]. Patients with pathological fractures, osteoporosis, and severe obesity were excluded.

A total of 48 male and 24 female patients with an average age of 45.10 years (range, 26–63 years old) were enrolled in the study. Anatomical levels were L_1 (30 [41.70%]), T_{12} (8 [25.00%]), L_2 (16 [22.20%]), and T_{11} (8[11.10%]). Causes of injuries were as follows: motor vehicle accident (22 patients), falling (44 patients), and heavy pound injury (6 patients). Furthermore, 18 (25%) patients suffered from multiple injuries, including cervical fracture (2 patients), sacrococcyx fracture (2 patients), pelvic fracture (4 patients), limb fracture (6 patients), and rib fracture (4 patients). According to AO classification, all cases were A3 fractures. Furthermore, the average load-sharing score was 7.9 (range, 6–9) and the average injury surgery interval was 9.8 days (range, 5–28 days).

The study protocol was approved by the Ethics Committee of the Affiliated Hospital of Southwest Medical University. Informed consent was obtained from patients prior to inclusion in the study.

Interventions

Patients were randomly divided into two group, including an observation group (n = 36) and a control group (n = 36). The age of those in the observation and control groups were 44.80 ± 10.1 and 45.32 ± 9.6 years, respectively. The load sharing classification score (LSC) of these two groups were 7.99 ± 1.22 and 7.80 ± 1.07, respectively. The injury surgery interval (ISI, days) of these two groups were 9.56 ± 4.80 and 9.98 ± 4.77, respectively. The fusion time (FT, months) of these two groups were 13.75 ± 7.40 and 13.96 ± 7.77, respectively. The follow-up (FU, months) of these two groups were 39.88 ± 18.01 and 40.20 ± 18.23, respectively. No significant differences in these five indexes were found between observation and control groups. No significant differences in age, gender, and other basic information were found between the two groups.

The quadrant positioning method was used for screw insertion in the observation group during the surgical operation. Details of the quadrant positioning method: the lateral view of the intact thoracolumbar vertebral body above or below the excision was divided into four quadrants using two lines (horizontal and vertical lines), and both lines crossed the center of the vertebral body (Fig. 1A). These four quadrants, which include the superior anterior (SA), superior posterior (SP), inferior anterior (IA), and inferior posterior (IP) quadrants, could be easily targeted during the operation. The screw entry point was the center of each quadrant. In general, the two screws in the cranial vertebral body were located at the center of SP and IA, and the screws in the caudal vertebral body were located at the center of IP and SA, when double screw–rod anterior instrumentation was used for fixation (Fig. 1B). For the direction of the screw, the posterior screw was approximately 5°–10° forward in the axial plane and parallel to the endplate in the sagittal plane, while the anterior screw was approximately 5° backward in the axial plane and parallel to the endplate (Fig. 1C). Because the entry point was determined by quadrant division, we named this technique the quadrant positioning method.

Surgeries Performed Following Steps Mentioned Below

Position and Exposure

After general anesthesia, patients were placed in the right lateral decubitus position with a high cushion under the injury region. Skin incision with a length of approximately 12 cm was made, and conventional left thoracophrenolombotomy was performed for anterior lateral exposure. Mobile C-arm

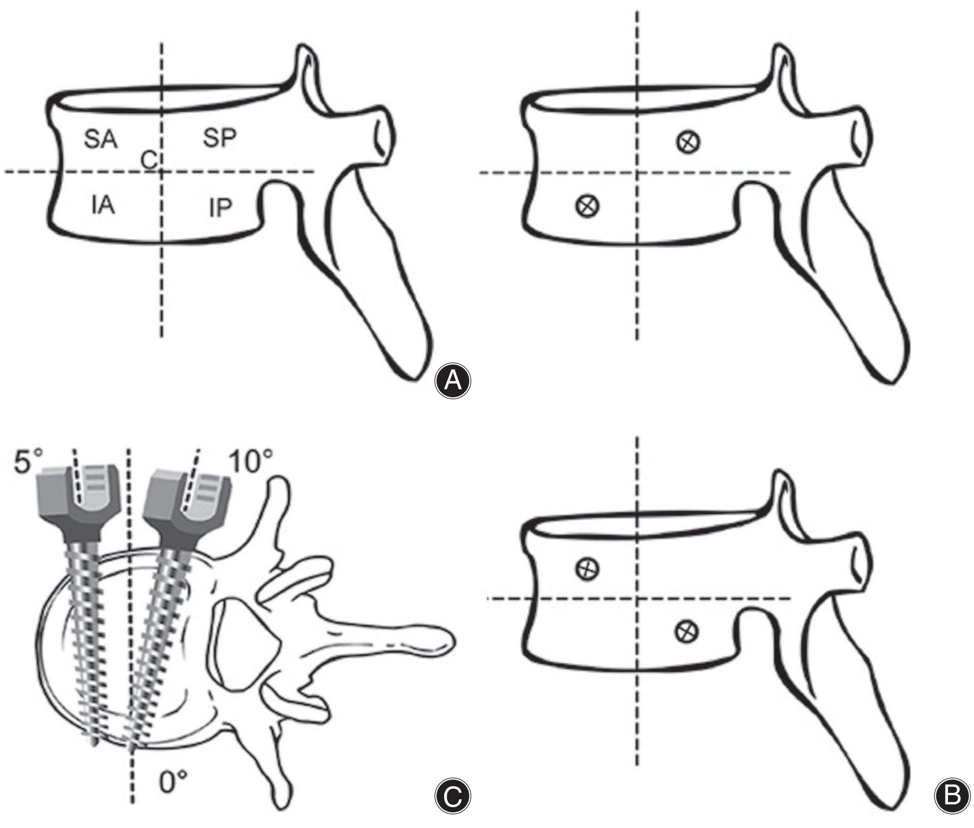

Fig. 1 Quadrant method: (A) Four quadrants were divided in the lateral vertebral body by two lines. Point C was the center of the body. IA, inferior anterior quadrant; IP, inferior posterior quadrant; SA, superior anterior quadrant; SP, superior posterior quadrant. (B) The screw entry point was the center of the quadrant. (C) Screw trajectories revealed that the posterior screw was approximately 5°–10° forward and the anterior screw was approximately 5° backward.

fluoroscopy was used to confirm the fracture level. Then, the segmental vessels at the fractured and caudal adjacent levels were securely ligated. The left lateral vertebral bodies were clearly exposed, where the most anterior, the most posterior, as well as the upper and lower endplate, were identified with a blunt probe.

Quadrant Positioning Method

Lateral views of the intact body adjacent to the fracture level were divided into four quadrants by two lines marked with an electrotome using the aforementioned method. The four quadrants (SA, SP, IA, and IP) were targeted during the operation. The center of each quadrant was identified as a screw entry point. Then, the posterior two screws were inserted in the SP and IP quadrants using the quadrant positioning method described above at the cranial and caudal adjacent vertebrae after discectomies. An anterior holder was installed for reduction and distraction between the two posterior screws. The anterior two screws were inserted in the SA and IA quadrants after corpectomy and decompression. Figure 2 shows the anterior distractor between the posterior screws.

Decompression and Instrumentation

Corpectomy and decompression were performed according to techniques described in previous studies[13,14]. Then, a titanium cage (Pyramesh Medtronic, Memphis, USA) or an artificial vertebral body filled with morselized autologous cancellous bone was packed with autograft taken from the corpectomy defect. After the holder was removed and a rod was installed, a mobile C-arm was used to inspect the reduction and alignment of the thoracolumbar region. If the inspection was satisfactory, another two screws were inserted in the selected quadrants and another rod was installed. Two cross-links were connected with the former rods to augment torsional rigidity. Double screw–rod anterior instrumentation (Shandong Weigao Group, China) was used for every case, and both screws were ensured bicortical fixation in each vertebral body adjacent to the fracture level. Routine closure was carried out, and a drain retained if necessary.

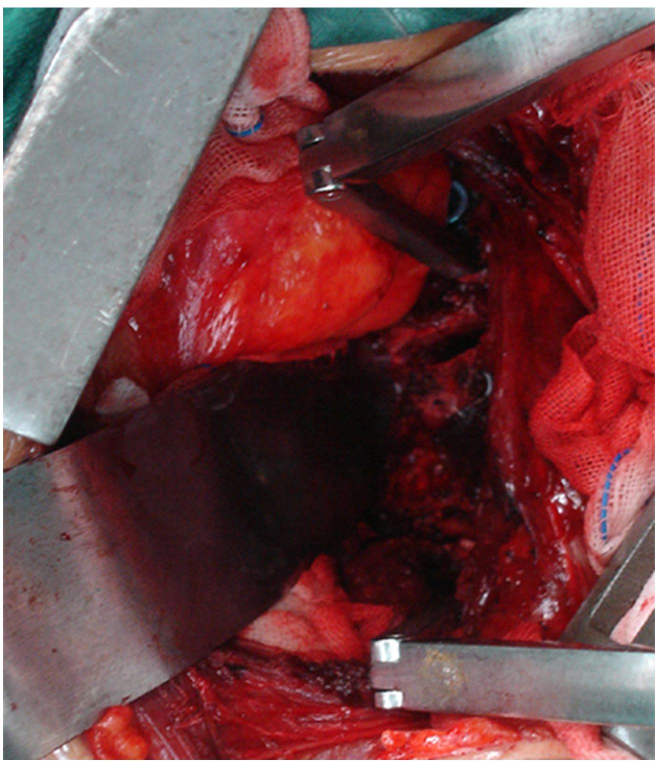

Fig. 2 Distraction was performed using an anterior distractor between the posterior screws.

Comparisons

Patients in the control group were treated in the same way except that the quadrant positioning method was not used for screw insertion. The traditional screw positioning method was used in the control group; that is, four screws were inserted into the vertebral bodies above and below the excision, 8 mm from the most posterior of the vertebral body and 8 mm from the endplate.

Outcomes

Kyphotic angle (KA), lateral angle (LA), and anterior vertebral body height (AH) were measured using radiographs (Fig. 3) before and 1 week after surgery, and at the end of follow-up.

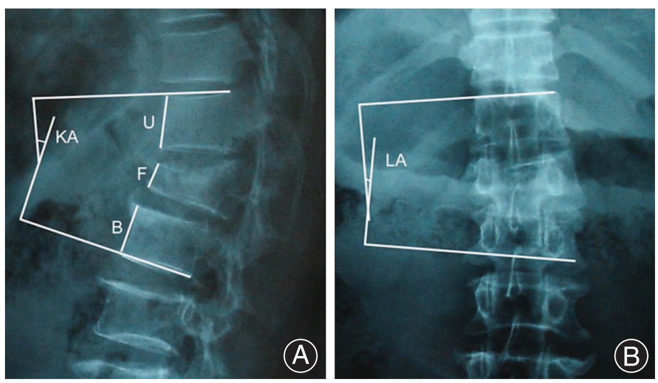

Fig. 3 Measurement of parameters: (A) The kyphotic angle (KA) was measured as the Cobb angle between the upper endplate of the vertebral body above the fracture level and the lower endplate of the vertebral body below the fracture level in the sagittal plane. The anterior vertebral body height (AH) remaining rate was determined using the formula $AH = 2F/(U + B) \times 100\%$, where F was the height of the fractured vertebral body, U was the height of the upper vertebral body, and B was the height of the lower vertebral body. (B) The lateral angle (LA) was measured as the angle between the upper endplate of the vertebra above the fracture level and the lower endplate of the vertebral body below the fracture level in the coronal plane.

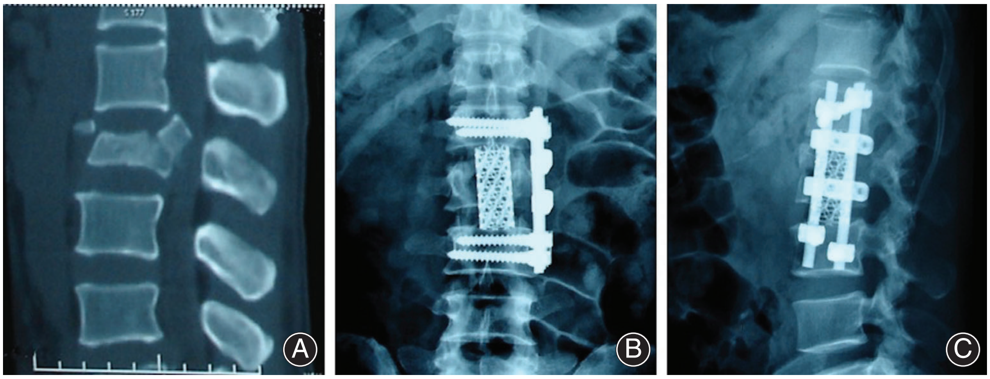

Fig. 4 An L_2 unstable fracture treated using the quadrant method. (A) Lateral X-ray and CT reconstruction image before the operation. (B) AP view after the operation. (C) Lateral view after the operation.

Kyphotic Angle, Lateral Angle, and Anterior Vertebral Body Height

The KA was measured as the Cobb angle between the upper endplate of the vertebral body above the fracture level and the lower endplate of the vertebral body below the fracture level in the sagittal plane. LA was measured as the angle between the upper endplate of the vertebra above the fracture level and the lower endplate of the vertebral body below the fracture level in the coronal plane. AH was the anterior vertebral body height remaining rate of the fracture level.

Frankel Grade

Neurological assessment was performed based on the Frankel grade system before surgery and at the end of follow-up. The Frankel grade classification provides an assessment of spinal cord function and is used as a tool in the treatment of spinal cord injuries. There are A to E grades: Grade A, complete neurological injury; Grade B, preserved sensation only; Grade C: preserved motor, nonfunctional; Grade D: preserved motor, functional; Grade E: normal motor function.

Other Indexes

In addition, patient demography, injury cause, associated lesions, blood loss, operation time, hospital stay, and complications were assessed and compared carefully.

Statistical Analysis

Measurement (measured indicators) data were expressed as mean ± SD and compared with the *t*-test. Count data (gender and neurological assessment) were compared using the χ^2-test. All statistical analyses were performed using GraphPad Prism 6 software (GraphPad Software, San Diego, CA, USA). $P < 0.05$ was considered statistically significant.

Results

Accurate Screw Positioning was Achieved with the Quadrant Positioning Method

The quadrant center in the lateral view of the vertebral body was well marked, and all screws were inserted without mobile C-arm fluoroscopy guidance. The postoperative radiography revealed that the screw was well-located in the scheduled quadrant. The images of a typical patient are showed in Fig. 4. No intraoperative spinal cord injury was observed.

Quadrant Method Improved Intraoperative Parameters

As shown in Table 1, blood loss (BL), hospital stay (HS), and operation time (OP) in observation group were 749.40 ± 379.90 mL, 17.10 ± 4.10 days, and 167.40 ± 44.70 min, respectively. While those parameters in the control group were 1198.40 ± 339.27 mL, 23.22 ± 3.77 days, and 221.47 ± 32.15 min, respectively. The average operation time and hospital stay time were significantly shorter, and blood loss was significantly less in the observation group than in the control group ($P < 0.05$).

Kyphotic Angle, Lateral Angle, and Anterior Vertebral Body Height Improved in Both Groups

Kyphotic angle (KA, °) in the observation group at three time points including preoperation, 1 week after operation, and final follow-up was 15.10 ± 6.70, 1.60 ± 4.00, and 1.50 ± 3.60, respectively; KA (°) in the observation group at three time points was 15.66 ± 7.3, 1.64 ± 3.22, and 1.55 ± 3.12, respectively; lateral angle (LA, °) in the observation group at three time points was 5.20 ± 3.90, 2.00 ± 2.20, and 1.40 ± 1.60, respectively; LA (°) in the control group at three time points was 5.37 ± 3.29, 2.33 ± 1.89, and 1.35 ± 1.12, respectively; anterior vertebral body height (AH, %) in the observation group at three time points was 60.70 ± 15.70, 90.90 ± 7.30, and 89.60 ± 7.10, respectively; LA (°) in the control

TABLE 1 Comparison of intraoperative parameters between the two groups (mean ± SD)

Indexes	Observation group	Control group	*P*-value
BL (mL)	749.40 ± 379.90	1198.40 ± 339.27	<0.05
HS (day)	17.10 ± 4.10	23.22 ± 3.77	<0.05
OP (min)	167.40 ± 44.70	221.47 ± 32.15	<0.05

BL, blood loss; HS, hospital stay; OP, operation time.

TABLE 2 Comparison of kyphotic angle, lateral angle, and anterior vertebral body height at different time points in the two groups (mean ± SD)

	Preoperation		One week after operation		Final follow-up	
Parameters	Observation group	Control group	Observation group	Control group	Observation group	Control group
KA (°)	15.10 ± 6.70	15.66 ± 7.32	1.60 ± 4.00*	1.64 ± 3.22*	1.50 ± 3.60*	1.55 ± 3.12*
LA (°)	5.20 ± 3.90	5.37 ± 3.29	2.00 ± 2.20*	2.33 ± 1.89*	1.4 ± 1.60*	1.35 ± 1.12*
AH (%)	60.70 ± 15.70	59.98 ± 13.87	90.90 ± 7.30*	87.77 ± 8.44*	89.60 ± 7.10*	85.37 ± 6.19*

* Compared with preoperation level within the same group, $P < 0.05$; AH, anterior vertebral body height; KA, kyphotic angle; LA, lateral angle.

group at three time points was 59.98 ± 13.87, 87.77 ± 8.44, and 85.37 ± 6.19, respectively. Comparison of KA, LA, and AH at different time points showed that, compared with preoperation levels, KA, LA, and AH were significantly improved in both groups at 1 week after surgery. No further significant improvement was observed at the end of follow up. No significant differences in KA, LA, and AH were found between the two groups at each time point. See Table 2 for details.

Frankel Grade Improved in Both Groups

Neurological assessment was performed based on the Frankel grade system before surgery and at the end of follow-up. As shown in Table 3, compared with preoperation levels, neurological functions were significantly improved in both groups ($P < 0.05$). No significant differences in neurological scores were found between the observation group and the control group at both time points ($P > 0.05$, χ^2-test, data not shown).

Discussion

Proper Screw Insertion is a Hot Research Topic

Proper screw insertion is one of the important factors for successful reconstruction and inter-fixation of the thoracolumbar region. However, only a few studies on anterior screw insertion have been documented. Rao *et al.* describled that anterior screw positioning was 8 mm from the most posterior of the vertebral body and 8 mm from the endplate for Z-plate installation[15]. Kanada *et al.* reported that four screws were inserted into the vertebral bodies above and below the excision and fixed in a trapezoidal configuration[10]. These techniques are effective for proper screw insertion, but the definite parameters may be difficult to measure during the operation, especially for inexperienced operators. Although the lateral view of a thoracolumbar vertebral body is relatively wide and screw insertion is not difficult, improper screw placement may have severe consequences, including neurological or vascular injury, penetration of the intact disc, and unbalanced fixation. Thus, the technique for anterior screw insertion remains important.

Quadrant Positioning Method Improves Treatment Outcomes

Our study developed the quadrant positioning method for effective screw insertion. This method is an improvement on traditional screw positioning in anterior thoracolumbar surgery and may provide an easy approach to improve the accuracy for screw insertion. In fact, our data showed that, compared with the traditional method, the quadrant positioning method significantly reduced the operation time, which, in turn, reduced blood loss and accelerated postoperative recovery. The quadrant concept has already been used in orthopedic surgery[16–18]. Satish *et al.* presented a modified screw fixation technique for femoral neck fractures, which was termed four quadrant parallel peripheral (FQPP) fixation[17]. However, as far as we know, application of a quadrant positioning method in anterior surgery for thoracolumbar fracture has not been reported. During the operation, the lateral view of the vertebral body was divided into four quadrants using two virtual lines, and screw positioning was located at the center of the quadrant. The screw direction may be determined with the exposure of the endplate following discectomy. Similarly, in previous studies[10,15], a 5°–10°

TABLE 3 Comparison of neurological assessment scores obtained through Frankel grade system at different time points in two groups (cases)

Groups	Time points	A	B	C	D	E	χ^2	*P* value
Observation group	Preoperation	1	3	6	8	18	11.62	0.02
	Final follow-up	1	1	1	2	31		
Control group	Preoperation	1	3	7	7	18	13.92	0.01
	Final follow-up	1	1	1	1	32		

forward inclination for posterior screws and a 5° backward inclination for anterior screws were recommended for safety. Thus, these screws may be precisely and easily inserted into the vertebral body.

Anterior Surgery Preferred for Thoracolumbar Fracture

Our study also confirmed the advantages of anterior surgery for thoracolumbar fractures, which were consistent with those reported in the published literature[6–10,19]. In a retrospective study of anterior stabilization, Zhang *et al.* reported that the kyphotic angle obviously improved, average operation time was 412.30 min, and estimated blood loss was 1098 mL[6]. Sharma *et al.* evaluated the outcome of anterior instrumentation for thoracolumbar burst fractures and reported that the kyphotic angle was improved from 23° to 7°[19]. The present study demonstrated that the local angle was corrected and lasted satisfactorily. Furthermore, anterior vertebral body height was obviously improved (from 60.7% preoperatively to 90.9% postoperatively), which was similar to results in earlier studies[6,19]. In the present study, the average operation time was 167.40 min and blood loss was 749.40 mL; bigger improvements were made compared the parameters reported by Zhang *et al.*[6].

Adverse Effects of Anterior Approach are Acceptable but can be Further Inhibited

However, trauma from anterior surgery for thoracolumbar fracture remains a concern, and complications, such as massive hemorrhage, hemothorax, pleural injury, lung infection, and retrograde ejaculation, may not be avoided[8,9,19,20]. In the present study, 9 cases in the observation group (25%) and 10 cases in the control group (27.8%) had complications of cerebrospinal fluid (CSF) leaking, hemothorax, and urinary and lung infection. All patients with complications were cured and free of complaints during the follow-up. In particular, 1 patient in the observation group had chylous leakage. This may have been due to direct injury of the retroperitoneal lymphatic trunk by surgical maneuver. As reported in a previous study[21], chylous leakage is a rare complication that occurs after retroperitoneal surgery, which may spontaneously heal. The patient recovered after conservative treatment, including drainage, fasting, albumin transfusion, and total parenteral nutrition. Hence, the adverse effects of the anterior approach remained acceptable, while reduction of those adverse effects may be a direction of future studies.

Conclusions

The quadrant positioning method is an easy and effective means of screw insertion for double screw–rod instrumentation fixation for treating thoracolumbar fractures *via the* anterior approach. Using this method shortens the operation time, reduces blood loss, and accelerates postoperative recovery. This method may also be used for other diseases, such as thoracolumbar tuberculosis and tumors. Our study is limited by the small sample size. Future studies with bigger sample sizes are needed to further confirm our conclusion.

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