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ORIGINAL ARTICLE

A comparison of hidden blood loss between the Wiltse approach with pedicle screw fixation and the percutaneous pedicle screw fixation for neurologically intact thoracolumbar fractures

Ding Hu, MD[1], Yu He, MD[1], Yin-xiao Peng, MD[2], Shanchuan Wei, MD[3]

[1]Department of Spine Surgery, Chengdu Second People's Hospital, Chengdu, Sichuan, China
[2]Department of Orthopaedics, The Third People's Hospital of Chengdu, Sichuan, China
[3]Department of Joint and Traumatology, People's Hospital of ChangShou, Chongqing, China

ABSTRACT

Objectives: This study aims to quantify hidden blood loss (HBL) associated with minimally invasive pedicle screw placement and to compare HBL between the Wiltse approach and percutaneous pedicle screw techniques.

Patients and methods: Between January 2020 and December 2022, a total of 126 neurologically intact patients (63 males, 63 females; mean age: 43.0 ± 11.5 years; range, 18 to 65 years) with single-segment traumatic thoracolumbar fractures who underwent surgery were retrospectively analyzed. The patients were categorized into two groups based on surgical technique: the study group (Wiltse approach) and control group (percutaneous pedicle screw). Demographic and clinical data were collected. Perioperative laboratory values were recorded, and HBL was calculated using a combination of the Nadler, Gross, and Sehat formulas.

Results: The Wiltse approach group demonstrated a significantly shorter surgical time and fewer intraoperative fluoroscopy uses compared to the percutaneous group ($p < 0.001$ for both). Although intraoperative visible blood loss (VBL) was higher in the Wiltse group ($p < 0.001$), this group showed a smaller postoperative hemoglobin loss ($p = 0.025$) and significantly less HBL in absolute volume ($p = 0.031$).

Conclusion: In minimally invasive surgery for single-segment thoracolumbar fractures, perioperative HBL considerably exceeds VBL. Compared to the Wiltse approach, percutaneous pedicle screw fixation is associated with longer operation time, greater radiation exposure, and higher HBL. Therefore, spine surgeons should emphasize close monitoring of postoperative hemoglobin and appropriate management of anemia in patients undergoing percutaneous instrumentation.

Keywords: Hidden blood loss, minimally invasive surgery, percutaneous pedicle screw fixation, thoracolumbar fractures. Wiltse approach.

Thoracolumbar fractures are among the most common spinal injuries, with a high incidence between T11 and L2, accounting for approximately 60 to 70% of all spinal trauma cases.[1-3] Treatment options range from conservative management to surgical intervention, with surgery often recommended for unstable injuries. The Load-Sharing Classification (LSC) is one tool used in this decision-making, where a score above 7 is frequently cited as an indicator for surgical stabilization.[4] Early surgical stabilization helps restore spinal alignment, provide stability, and facilitate rehabilitation.[5]

While traditional open surgery remains effective, it is associated with substantial soft tissue disruption, significant blood loss, and

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Correspondence: Shanchuan Wei, MD. Department of Joint and Traumatology, People's Hospital of ChangShou, Chongqing, China.

E-mail: lianhuwsc@163.com

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higher complication rates.[6,7] Minimally invasive surgery (MIS) has, therefore, gained popularity for managing neurologically intact thoracolumbar fractures, owing to advantages such as reduced muscle dissection, less intraoperative bleeding, and faster recovery.[8-10] Percutaneous pedicle screw fixation and the Wiltse approach are the two main MIS techniques.

Despite these benefits, a growing body of literature indicates that MIS is not devoid of substantial perioperative blood loss. Notably, the concept of hidden blood loss (HBL),[11] blood loss that is not captured in the suction canister or surgical sponges, has been increasingly identified as a major component of total blood loss (TBL) in various spinal procedures.[12-15] Significant HBL can lead to postoperative anemia, which has been documented in procedures such as spinal osteotomies,[12] extreme lateral interbody fusion,[13] and percutaneous endoscopic discectomy,[14] even in the presence of limited visible blood loss (VBL).

While non-operative management is the mainstay for neurologically intact AO type A fractures (i.e., compression injuries with an intact posterior ligamentous complex [PLC]), a subset of patients may opt for surgical intervention due to factors such as intractable pain, high functional demand for early mobilization, or concerning radiological parameters at the time of presentation. In such cases, MIS techniques are favored. However, the phenomenon of HBL in these MIS procedures is often overlooked. Given the increasing recognition of HBL in spinal surgery and its potential clinical impact, a detailed understanding of its magnitude in different MIS techniques is crucial. A recent study by Jiang et al.[16] similarly compared HBL between percutaneous and Wiltse approaches for thoracolumbar fractures and found lower HBL in the Wiltse group. While their findings are insightful, independent validation is essential in clinical research to confirm generalizability. Furthermore, a comprehensive analysis of the proportion of blood loss that remains hidden (HBL/TBL ratio) has not been previously reported. In the present study, we, therefore, aimed to assess HBL comparing these two techniques, to analyze the novel metric of the HBL/TBL ratio, and to provide a broader comparison of perioperative outcomes to offer a more complete clinical picture.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Chengdu Second People's Hospital, Department of Spine Surgery between January 2020 and December 2022. We conducted a retrospective review of patients treated for thoracolumbar fractures. The patients were thoroughly counseled regarding conservative and surgical management options preoperatively, with treatment selection guided by patient choice. Eligible participants met the following criteria: (1) skeletally mature adults aged above 18 years; (2) presence of an acute single-segment thoracolumbar fracture (T10-L2, AO Type A); (3) having no neurological impairment; (4) treatment with minimally invasive pedicle screw instrumentation via either the Wiltse or percutaneous approach; and (5) complete clinical and radiographic data. All patients underwent preoperative computed tomography (CT) and magnetic resonance imaging (MRI). The latter was crucial for assessing the integrity of the PLC to definitively rule out B-type injuries and for evaluating spinal cord and soft tissue status. Key exclusion criteria included: (1) spinal canal stenosis at the fractured level; (2) history of spinal surgery; (3) fractures related to osteoporosis, neoplasms, or tuberculosis; (4) polytrauma; (5) coagulopathies or recent use of antiplatelet/non-steroidal anti-inflammatory drugs (NSAIDs); (6) active systemic or local infection; (7) significant cardiopulmonary, renal, or cerebral comorbidity posing a contraindication to surgery; and (8) psychiatric illness compromising cooperation. While the LSC score is a recognized factor in considering surgical intervention, it was not utilized as a formal inclusion or exclusion criterion for this study. The decision for surgery was based on the comprehensive, patient-centered process described above. After screening, a total of 126 neurologically intact patients (63 males, 63 females; mean age: 43.0±11.5 years; range, 18 to 65 years) with single-segment traumatic thoracolumbar fractures who underwent surgery were included. This study was reviewed and approved by the Ethics Committee of Chengdu Second People's Hospital. The committee confirmed that the research conformed to the principles of the Declaration of Helsinki. Because the study was retrospective in nature and did not include any specific interventions for patients, verbal approval was considered sufficient.

The decision to proceed with surgical intervention was made collaboratively between the surgeon and the fully informed patient, consistent with contemporary clinical practice that emphasizes individualized treatment. Surgery was offered

for A1/A2 type fractures only in the presence of additional clinical factors such as: (1) failure of conservative pain management, (2) a high functional demand necessitating early stabilization and mobilization (e.g., manual laborers), or (3) patient preference after detailed discussion of the risks and benefits of both operative and non-operative strategies. This explains the composition of our study cohort.

Surgical procedure

The choice of surgical technique (Wiltse or Percutaneous) was determined through a shared decision-making process between the attending surgeon and the patient. For all included fractures, both techniques were deemed technically feasible. The surgeon would present the options, discussing the potential advantages and disadvantages of each (e.g., the percutaneous technique typically involves smaller incisions but may require more fluoroscopy; the Wiltse approach offers direct visualization and may facilitate a shorter operative time). The surgeon's recommendation could be influenced by specific fracture characteristics (e.g., degree of comminution) or patient factors (e.g., body habitus). The final decision incorporated the surgeon's clinical expertise and the patient's informed preference based on this discussion. All surgeries were carried out under general anesthesia by a single consistent surgical team. The operative techniques differed between groups:

1. In the Wiltse approach (study group) cohort, patients were placed prone with abdominal decompression. A midline incision (~8 cm) was made over the fracture site. Through a paramedian fascial opening, the natural plane between the multifidus and longissimus muscles was developed to expose bony anatomy. Six pedicle screws were inserted, and reduction was achieved with longitudinal rods before wound closure.
2. In the percutaneous (control group) cohort, patients were similarly positioned, and six short stab incisions (1.5 cm each) were created under fluoroscopy. Pedicle access was obtained using a needle and dilators, followed by screw placement. Pre-bent rods were inserted subcutaneously to reduce the fracture, with final imaging verification before closure.

Both groups received 24-h prophylactic antibiotics. Postoperative rehabilitation included day-1 lower limb exercises, day-3 lumbar mobilization, and 2-week suture removal. Minimum follow-up was 12 months.

Data collection

Demographic data including age, sex, height, weight, and body mass index (BMI), injury-related details including mechanism of injury, time from injury to surgery, Visual Analog Scale (VAS) score, fracture level, and AO classification, and perioperative indicators including American Society of Anesthesiologists (ASA) grade, incision length, operation time, number of fluoroscopies, hemoglobin (Hb), albumin (ALB), and hematocrit (Hct) were recorded. Intraoperative VBL was measured based on suction canister fluid volume and the weight of saturated gauzes. No blood transfusions were administered during any procedure.

Calculation of blood loss

Patient blood volume (PBV) was estimated using gender, height, and weight, according to the following formula:[17]

For males: PBV (L) = 0.3669 × height $(m)^3$ + 0.03219 × weight (kg) + 0.6041

For females: PBV (L) = 0.3561 × height $(m)^3$ + 0.03308 × weight (kg) + 0.1833

Total blood loss was derived using the Gross's formula:[18]

$$TBL\ (L) = PBV\ (L) \times (Hct_{pre} - Hct_{post}) / Hct_{ave},$$

where Hct_{pre} represents the preoperative Hct, Hct_{post} the Hct on postoperative Day 3, and Hct_{ave} the average of the two.

Hidden blood loss was defined as the difference between TBL and VBL, as described by Sehat et al.[11]

HBL = TBL - VBL

Notably, no surgical drains were used in either group, allowing all intraoperative blood loss to be accounted for as VBL.

Statistical analysis

Statistical analysis was performed using the SPSS version 26.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were presented in mean ± standard deviation (SD) or median (min-max), while categorical variables were presented in number and frequency. Continuous variables were compared using the independent samples t-tests. Categorical variables were analyzed using the chi-square or Fisher exact tests. A p value of < 0.05 was considered statistically significant.

TABLE I
Comparison of demographic and baseline clinical characteristics between the Wiltse approach group and the percutaneous pedicle screw fixation group

	Study group (n = 56)		Control group (n = 70)		
Variables	n	Mean ± SD	n	Mean ± SD	*p*
Age (year)		42.8 ± 12.2		43.2 ± 11.0	0.859
Sex					0.282
Male	31		32		
Female	25		38		
Height (m)		1.66 ± 0.03		1.65 ± 0.05	0.539
Weight (kg)		61.8 ± 6.6		60.8 ± 6.4	0.397
Body mass index (kg/m^2)		22.5 ± 2.4		22.3 ± 2.5	0.644
Mechanism of injury					0.961
Traffic accident	27		37		
Accidental falls	18		20		
Fall from height	7		8		
Others	4		5		
Time from injury to surgery (day)		4.86 ± 1.84		4.84 ± 1.80	0.965
Visual Analog Scale		6.5 ± 1.1		6.7 ± 1.1	0.210
Fracture segment					0.866
T11	24		32		
T12	22		23		
L1	6		10		
L2	4		5		
AO classification					0.810
A1	33		45		
A2	15		17		
A3	8		8		

SD, standard deviation.

TABLE II
Comparison of surgical and postoperative parameters between the two groups

	Study group (n = 56)		Control group (n = 70)		
Variables	n	Mean ± SD	n	Mean ± SD	*p*
ASA classification					0.764
I	8		13		
II	33		41		
III	15		16		
Length of incision (cm)*		8.6 ± 1.7		8.6 ± 1.5	0.792
Surgical time (min)		61.3 ± 5.0		74.1 ± 6.6	< 0.001
Number of fluoroscopy (n)		8.4 ± 1.4		12.4 ± 2.5	< 0.001
Length of stay (day)		5.5 ± 1.2		5.4 ± 1.2	0.585
Follow-up time (month)		15.8 ± 2.2		15.6 ± 2.5	0.553

SD, standard deviation; ASA, American Society of Anesthesiologists; * for the Study group (Wiltse), this refers to the single midline incision length. For the Control group (Percutaneous), this represents the cumulative sum of all six stab incisions.

RESULTS

Of the 126 participants, traffic accidents constituted the primary mechanism of injury. The T11 vertebra was most frequently involved (44.4%). Epidemiological and baseline clinical variables were evenly distributed across groups (Table I).

TABLE III
Comparison of VBL, TBL, HBL, and related hematologic parameters between the two groups

Variables	Study group (n = 56) Mean ± SD	Control group (n = 70) Mean ± SD	*p*
Intraoperative blood loss (mL)	85.4 ± 9.2	55.9 ± 7.3	< 0.001
Preoperative Hct (%)	0.40 ± 0.03	0.40 ± 0.02	0.251
Postoperative Hct (%)	0.37 ± 0.03	0.36 ± 0.02	0.301
Hct loss (%)	0.032 ± 0.004	0.032 ± 0.005	0.543
Preoperative Hb (g/L)	130.9 ± 6.5	131.6 ± 5.3	0.542
Postoperative Hb (g/L)	121.5 ± 8.0	119.4 ± 8.3	0.152
Hb loss (g/L)	9.4 ± 5.5	12.2 ± 7.6	0.025
PBV (L)	4.1 ± 0.3	4.0 ± 0.4	0.169
TBL (mL)	343.8 ± 46.2	333.2 ± 49.6	0.222
HBL (mL)	258.4 ± 47.0	277.3 ± 49.3	0.031
HBL/TBL (%)	74.7 ± 4.2	82.9 ± 3.2	< 0.001

VBL, visible blood loss; TBL, total blood loss; HBL, hidden blood loss; PBV, patient blood volume; Hct, hematocrit; Hb, hemoglobin. VBL was measured intraoperatively. TBL was calculated using Gross's formula based on PBV and Hct changes. HBL was obtained as TBL-VBL. Preoperative and postoperative values were measured before surgery and on postoperative Day 3, respectively.

TABLE IV
Postoperative complications recorded during hospitalization and follow-up

	Study group (n = 56)		Control group (n = 70)	
	n	%	n	%
Spinal cord injury	0	0	0	0
Screw misplacement	0	0	0	0
Cerebrospinal fluid leakage	0	0	0	0
Wound infection	0	0	1	1.4
Deep venous thrombosis	1	1.8	0	0
Pneumonia	1	1.8	0	0
Urinary tract infection	0	0	1	1.4

Patients undergoing the Wiltse approach had significantly shorter operative durations and fewer fluoroscopy exposures than those receiving percutaneous surgery ($p < 0.001$ for both). There were no significant differences in the ASA class, incision length, hospital stay, or follow-up period between the groups (Table II). Although VBL was higher in the Wiltse cohort ($p < 0.001$), this group exhibited smaller reductions in Hb and lower HBL ($p = 0.025$ and $p = 0.031$, respectively). The HBL/TBL ratio was also significantly lower in the Wiltse group ($p < 0.001$) (Table III). There were no neurological or vascular complications. One superficial infection occurred in the percutaneous group and healed with antibiotics (Table IV).

DISCUSSION

In the present study, we attempted to quantify HBL associated with minimally invasive pedicle screw placement and compared HBL between the Wiltse approach and percutaneous pedicle screw techniques. Our findings indicated that HBL constituted the predominant component of TBL across both MIS techniques, substantially exceeding VBL. The significant difference in HBL between the two techniques, despite similar fracture patterns, suggests that the surgical approach itself is a major determinant of occult blood loss. The mechanisms for HBL are likely not uniform but are technique-specific. The percutaneous technique, while minimizing visible skin incisions, involves

iatrogenic soft tissue trauma from the sequential dilation of paraspinal muscles and the insertion of screws without direct visualization. This likely causes substantial capillary bleeding and microvascular damage within the muscle bulk and subcutaneous tissues. Since this bleeding occurs out of the surgeon's view, it is not amenable to direct coagulation and thus manifests as significant HBL. Furthermore, the reliance on fluoroscopy rather than anatomical landmarks limits opportunities for identifying and controlling bleeding points during the procedure.

Conversely, the Wiltse approach, utilizing a natural intermuscular plane, provides direct visualization of the surgical field. This allows for identification of bleeding surfaces and facilitates precise electrocautery during dissection and screw placement. We postulate that this capacity for controlled intraoperative hemostasis, although it involves a larger initial dissection, effectively reduces the cumulative volume of blood lost into hidden compartments, resulting in a lower overall HBL compared to the percutaneous technique. Therefore, the difference in HBL is less related to the fracture morphology and more attributable to the differential soft tissue handling and hemostatic capabilities afforded by each minimally invasive technique.

Our results present a notable trade-off: the Wiltse approach was associated with a statistically significant increase in VBL compared to the percutaneous technique. This is an expected consequence of the mini-open dissection, which involves incision of fascial planes and exposes a larger surface area for bleeding, *albeit* under direct visualization. It is of utmost importance to contextualize this finding; the mean difference in VBL was approximately 30 mL, and the absolute value in the Wiltse group (85.4 mL) remains within a range that is usually considered low-risk for spinal surgery and was readily managed intraoperatively. The percutaneous technique, in contrast, minimizes immediate, visible bleeding by virtue of its minimal tissue dissection, resulting in a lower VBL.

However, the critical finding of our study was that this reduction in visible loss in the percutaneous group was offset by a significantly greater HBL. The clinical implications of VBL and HBL differ substantially. The VBL is acute, apparent to the surgeon, and can be actively addressed during the procedure. The HBL, on the other hand, is occult, contributes to postoperative anemia, and may delay recovery, potentially increasing the risk of complications such as fatigue, dizziness, and increased cardiac workload. Therefore, while the higher VBL in the Wiltse group is a genuine consideration, the significantly lower HBL may ultimately represent a more advantageous overall blood loss profile. The key clinical takeaway is that surgeons should not be reassured by a low VBL in percutaneous cases and must remain vigilant for the substantial HBL that is likely to follow.

Our findings confirm the results of the recent study by Jiang et al.,[16] which also reported significantly higher HBL in percutaneous procedures compared to the Wiltse approach. This independent validation from a different surgical center significantly strengthens the evidence for this phenomenon. However, our study extends beyond this confirmation by providing several new insights. First, we introduced the analysis of the HBL/TBL ratio, which reveals that not only is the absolute volume of HBL lower in the Wiltse group, but the very proportion of TBL that is hidden is also significantly reduced. Similarly, Fan et al.[19] found that the Wiltse approach was associated with shorter operation time and less fluoroscopy usage, which aligns with our results.

Moreover, the phenomenon of substantial HBL in MIS spine surgery has been increasingly recognized. Studies in different spinal procedures, such as spinal osteotomies in pediatric patients[12] and extreme lateral interbody fusion,[13] have also identified HBL as a major component of total perioperative loss. Our study adds to this body of evidence by specifically focusing on thoracolumbar fractures and directly comparing two common MIS techniques.

More critically, the percutaneous technique, while minimally invasive, involves blind muscle dilation and screw insertion. This iatrogenic soft tissue trauma can cause substantial bleeding into the muscular and subcutaneous compartments, which is not directly visible to the surgeon and thus manifests as HBL. The reliance on fluoroscopy rather than direct visualization also limits opportunities for pinpoint hemostasis during the procedure. These findings suggest that spine surgeons should not be reassured by apparently low intraoperative VBL in percutaneous cases. Close monitoring of postoperative Hb and early management of anemia are essential. Adjunctive strategies such as the use of tranexamic acid may be considered to reduce HBL, as evidenced in lumbar fusion surgery.[20-22]

Although our study provides a comparative analysis of HBL between two techniques, it is critical to address the potential for selection bias. The assignment to the Wiltse or percutaneous group was not randomized, but was the result of a shared decision-making process. While we demonstrated that baseline demographic and injury characteristics were well-balanced between the groups (Table I), we cannot rule out the influence of unmeasured confounders. To illustrate, surgeon preference for one technique for more complex fractures, or patient factors such as a strong aversion to radiation, could have systematically influenced the choice of procedure. This is an inherent limitation of the non-randomized design. However, the primary objective of this study was to quantify and compare HBL in a real-world clinical scenario where these techniques are applied, and we believe our findings remain valuable for informing surgical planning and postoperative care.

Nonetheless, this study has certain limitations. First, the study was designed as a retrospective study with a limited sample size. Second, the cases included in this study were from a single center and, thus, there may be some bias in the selection of patients. Third, we assessed HBL on postoperative Day 3 based on Hct, which may have led to an underestimation of HBL. In addition, the non-randomized, surgeon-and-patient-preferred selection of the surgical technique introduces a potential for selection bias, as discussed above, which may limit the direct comparability of the two groups. A multi-center, large-scale, prospective study is warranted in the future to further validate our findings. Fourth, our study cohort consisted predominantly of patients with AO type A1 and A2 fractures who elected to undergo surgery. This reflects a specific clinical scenario and may not be generalizable to all patients with these fracture types, the majority of whom are managed non-operatively. However, the primary objective of our study was to compare HBL between two techniques within this specific surgical population, not to define indications for surgery.

In conclusion, in minimally invasive surgical treatment of traumatic thoracolumbar fractures, perioperative HBL is much higher than VBL and should not be ignored. Although intraoperative blood loss was higher in the pedicle screw fixation via Wiltse approach, its Hb loss and HBL were lower than percutaneous pedicle screw fixation. Therefore, in patients undergoing percutaneous pedicle screw fixation, spine surgeons should be aware of the potential for substantial HBL and implement standardized postoperative Hb monitoring and anemia management protocols to facilitate rapid recovery.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: H.D., Y.H.: Conception and design; Y.H.: Collection and assembly of data; Y.X.P.: Analysis and interpretation of the data, statistical expertise; H.D.: Drafting of the article; S.C.W.: Critical revision of the article for important intellectual content. All authors read and approved the final manuscript.

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