Comparison of Hidden Blood Loss Between Cortical Bone Trajectory Screw Fixation and Traditional Pedicle Screw Fixation

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Abstract

Objective: This research aimed at examining the volume of hidden blood loss (HBL) in lumbar fusion surgery with two kinds of screw implanting techniques and evaluating HBL-related factors in the patient population receiving lumbar fusion surgery

Methods: A retrospective study was conducted targeting 104 patients with lumbar degenerative diseases and treated with TLIF from January 2017 to December 2018, and the CBT (cortical bone trajectory) technique and conventional PS (pedicle screw) technique were applied to 45 and 59 patients, respectively. The collected data covered patients' weight, height, BMI index, and operation time. It was followed by the recording of preoperative and postoperative hematocrit (HCT) of patients, based on which the blood loss was calculated by Gross's formula.

Results: The CBT and PS groups presented no significant difference in demographic characteristics ($p > 0.05$), but the average HBL of 280 ± 227 mL and 298 ± 232 mL as well as the average TBL of 603 ± 232 mL and 728 ± 321 mL, respectively. It indicated the difference of the two groups in TBL, but no significant difference in HBL. In addition, an association of HBL of two screw techniques with operation time, concomitant disease and age was found from the data analysis.

Conclusion: Large total blood loss incurred in lumbar fusion surgery, specifically with a lower value by the CBT technique than by the PS technique. Nonetheless, HBL occupied a large part of the total blood loss and it was identified in both groups. Thus, a good understanding of HBL will improve postoperative rehabilitation and guarantee patients' safety.

1 Introduction

Lumbar degeneration, a common disease in the clinic, involves lumbar spondylolisthesis, lumbar spinal stenosis, lumbar segmental instability and so on [1, 2]. Usually, it may cause such clinical symptoms such as numbness, lower limb or back pain, intermittent claudication and even defecation and sexual dysfunction, thus seriously lower the quality of life. According to the world disease burden data, Lancet ranks low back pain as the leading cause of human incapacity worldwide since 1990 [3]. In this context, how to treat lumbar degeneration has become a critical clinical topic [4].

Over the past ten decades, lumbar fusion is a well-accepted operation to treat lumbar degenerative diseases [5]. It requires strong fixation support with bilateral pedicle screws, which has better biomechanical strength and performance than other fixation methods. However, with the accelerated process of population aging, the number of osteoporosis patients experiences an upward trend [6]. Due to the installation of the pedicle screw in the cancellous bone and insufficient fixation strength of osteoporosis patients, the risk of pedicle screw loosening is greatly increasing, which leads to the failure of the operation [7].

In 2009, the cortical bone trajectory (CBT) was first reported by Santoni et al. for the lumbar pedicle screw [8]. In contrast to traditional pedicle screws, the CBT screw insertion through a medial entry point offers advantages to avoid wide exposure of the superior facet joint and to minimize muscle dissection, both providing reduced invasiveness [8]. Currently, innovative applications of CBT screws in lumbar fusion surgery have been widely reported. For instance, Mizuno et al. developed a new lumbar fusion technique (MIDLF) by combining CBT screw technique with minimally invasive lamina decompression [9]. Rodriguez et al. reported the application of CBT screws in the treatment of symptomatic adjacent segmental lumbar diseases under the guidance of CT, which shortened the operation time and reduced the amount of blood transfusion [10]. Despite the less intraoperative bleeding and postoperative drainage, anemia is still found to be one of the common perioperative complications after the CBT screw operation. During the past years, substantial research shows that most of the total perioperative blood loss is underlying [11]. However, no enough attention has been paid to the problem of HBL in spinal surgery, especially in CBT screw fixation. To make up this literature gap, this study performed a comparison of the perioperative HBL between the CBT screw technique and pedicle screw technique, followed by an analysis of factors that potentially affect HBL.

2 Materials And Methods

2.1 Patients: All the protocols were approved by the review board and ethics committee of the institution. Informed consent was obtained from all the patients. From December 1, 2017 to November 12, 2018, a total of 200 consecutive patients who underwent single-level TILF in our hospital were targeted. As shown in Table 1, 104 patients were left after the exclusion of 46 patients and classified into the CBT group (45 patients, 25 males and 20 females, aged 62.3 ± 8.0 y (mean $\pm$ SD) and the PS group (59 patients, 32 males and 27 females; aged 61.3 ± 11.1 y (mean $\pm$ SD)).

Table 1
Demographic and clinical characteristics of the included patients.

	CBT-TLIF group	PS-TLIF group	P
Number	45	59	
Sex(Male/female)	25/20	32/27	0.447
Age (y)	62.3 ± 8.0	61.3 ± 11.1	0.648
BMI(kg/m2)	23.2 ± 2.4	23.3 ± 3.2	0.856
Preoperative diagnosis			0.306
Lumbar degenerative diseases	39	49	
Lumbar instability	6	10	
Spinal lesion segments			
L3/4	2	3	
L4/5	39	46	
L5/S1	4	10	

Inclusion criteria are (i) indication for monosegmental TLIF due to lower lumbar disease (including spinal stenosis lumbar disc herniation, spondylolisthesis, foraminal stenosis, and painful disc degeneration); (ii) no previous history of blood system disease, and normal coagulation function indicated by preoperative examination; (iii) no infection in the perioperative period; (iv) blood pressure and blood sugar controlled at a relatively stable level during the perioperative period, specifically, within 160 / 90mmHg of blood pressure for hypertension patients and 11.0mmol/l of blood glucose for diabetic patients.

Exclusion criteria are (i) patients who underwent monosegmental TLIF but decompressed at more than 2 segments; (ii) perioperative infection; (iii) bilateral spinal canal decompression; (iv) poor control of blood pressure and blood glucose during perioperative period; (v) coagulation dysfunction indicated by preoperative examination; (vi) incomplete medical records.

2.2 Surgical Technique: All patients underwent general anaesthesia and took antibiotics 30 min before the operation. To eliminate the inter-observer bias, all operations were performed by one surgeon. Posterior decompression including unilateral facetectomy and laminotomy was carried out. Afterward, an intervertebral cage filled with autogenous bone obtained from the decompression was prepared and inserted into the intervertebral space through the transforaminal. According to surgeon preference, the CBT screw procedure (Fig. 1A) or the PS screw (Fig. 1B) procedure was used to fix the fused segment. In both groups, a reinfusion system was absent and fluoroscopy was used to identify the fused level. The two groups presented no differences in wound closure technique or dressings.

2.3 Collection and collation of data

2.3.1 General information of patients

A retrospective review of electronic medical records for all patients was conducted. Body mass index (BMI), weight, age, gender, height, operation time, length of hospital stay (LOS), and fusion segment were selected as variables.

2.3.2 Hematocrit (HCT) and hemoglobin (Hb)

To examine the changes of HCT and HB, their values in the blood routine of all patients were recorded before the operation and on the second or third day after the operation.

2.3.3 Management of Blood Loss

The demographic and clinical characteristics of patients were recorded. Length of hospital stay was from the patient's admission to discharge dates. Foot pumps and compression stockings were applied to the prevention of deep vein thrombosis.

Hemoglobin and hematocrit levels were recorded before the operation and on the second or the third postoperative day. Stable hemodynamics was found among patients (1). Moreover, the visible blood loss was recorded by an anesthesiologist in the operating room, including the sponge used in the operation and the blood in the suction bottle (minus the irrigation fluid used in the operation). Postoperative drainage was also collected.

2.3.4 Calculation of HBL

The hidden and visible blood loss, as well as blood volume after surgery, was calculated based on Nadler's formulae. Referring to the literature [3], we calculated the hidden blood loss by deducting the measured blood loss from the calculated total blood loss: Hidden blood loss = total blood loss-measured blood loss

During the calculation of the total blood loss, the estimation of the patient blood volume (PBV) in milliliters is difficult. Thus, Nadler's formulae were employed to calculate PBV [12].

$$PBV(L) = height^3 \times k_1 + weight(kg) \times k_2 + k_3$$

where $k_1 = 0.3669$, $k_2 = 0.03219$, and $k_3 = 0.6041$ for men,

and $k_1 = 0.3561$, $k_2 = 0.03308$, and $k_3 = 0.1833$ for women.

With Gross's formula, the total blood loss was calculated as [13].

$$\text{Total blood loss} = (PBV) \times \frac{Hct_{pre} - Hct_{post}}{Hct_{ave}}$$

Hct_{pre} was the initial preoperative Hct; Hct_{post} was the Hct on the second or third postoperative day; Hct_{ave} was the average of Hct_{pre} and Hct_{post}

The amount of Hidden blood loss based on the literature [14] was calculated as:

$$\text{HBL} = \text{TBL} - \text{DBL}.$$

$$\text{HBL}\% = \text{PBL} / \text{PBV} \times 100\%$$

Further, the Oswestry Disability Index (ODI) scores and Japanese Orthopaedic Association (JOA) scores were assessed at 1 month postoperatively.

2.4 Statistical analysis: all analyses were performed on SPSS statistical software (SPSS Inc., Chicago, IL, USA). Mean $\pm$ Standard Error of Mean SEM was used to express all data. The Student's test or chi-squared test was employed when necessary. Statistical significance was identified by $P < 0.05$.

3 Result

The present research involved 104 patients (45 in the CBT-TLIF group, 59 in the PS-TLIF group), with the demographics in Table 1. The CBT-TLIF group and the PS-TLIF group at the time of surgery obtained a mean age of 62.3 ± 8.0 and 23.3 ± 3.2 years old, ($P = 0.648$) and an average BMI of 23.2 ± 2.4 and $23.7 \pm 2.8 \text{ kg/m}^2$ ($P = 0.856$), respectively, consisting of 25 males and 20 females as well as 32 males and 27 females ($P = 0.447$). The above results revealed the two groups did not significantly differ in age, sex, BMI, and preoperative diagnosis (all $p > 0.05$). In addition, in the perioperative period, according to Table 2, the average operation time in the CBT-TLIF group was 135 ± 36 min, shorter than that in the PS-TLIF group of 147 ± 30 min, while no statistical difference was identified. However, the mean length of stay in the CBT-TLIF group (12.5 ± 2.5 days) was significantly shorter than that in the PS-TLIF group (14.8 ± 4.6 days) ($P = 0.003$).

Table 2
Comparison of hidden blood loss and related indexes between the two groups

	CBT-TLIF group	PS-TLIF group	P
Preoperative blood volume(L)	4.13 ± 0.54	4.06 ± 0.61	0.544
Total blood loss (mL)	603 ± 232	728 ± 321	0.029
Loss of HB (g/L)	18.3 ± 7.2	24.2 ± 15.8	0.022
Intraoperative blood loss (mL)	141 ± 90	193 ± 104	0.009
Postoperative drainage (mL)	182 ± 112	237 ± 194	0.093
Dominant Blood Loss (mL)	323 ± 144	430 ± 235	0.008
Hidden blood loss(mL)	280 ± 227	298 ± 232	0.693
Hidden blood loss as a percentage of total blood loss(%)	46.4 ± 21.9	39.2 ± 18.3	0.071
Operation time(min)	135 ± 36	147 ± 30	0.067
Hospital stay (days)	12.5 ± 2.5	14.8 ± 4.6	0.003
Number of postoperative anemia cases	17	22	
Percentage of postoperative anemia(%)	37.8	37.3	

Table 2 lists the mean values, which include recessive blood loss, dominant blood loss, postoperative drainage, intraoperative blood loss, total blood loss, and some indexes related to the calculation of blood loss. Before the operation, the total blood volume of the CBT-TLIF group was 4.13 ± 0.54L, similar to that of the PS-TLIF group at 4.061L and with no statistical difference (P = 0.544). The CBT-TLIF group presented a statistical difference from PS-TLIF group in the intraoperative blood loss (P<0.05). The intraoperative blood loss in the CBT-TLIF group and PS-TLIF group was 141 ± 90 ml and 193 ± 104, respectively. The total loss and hidden blood loss between two groups were compared as well. The CBT-TLIF group obtained the total loss of 603 ± 232 mL and the hidden loss of 280 ± 227 mL (46.4% of the former), lower than those of the PS-TLIF group at 728 ± 321 mL and 298 ± 232 mL (39.3% of the former). The two groups presented a significant difference in the total loss but no statistical difference in the hidden blood loss. From the point of loss of Hemoglobin, the result of the CBT-TLIF group at 18.3 ± 7.2 g is less than the PS-TLIF group at 24.2 ± 15.8g/L, showing a significant difference (P = 0.022). Among the 45 patients in the CBT-TLIF group, 17 developed anemia after the operation, with an incidence of 37.8%. In the PS-TLIF group, 22 of the 59 patients developed anemia after the operation, with an incidence rate of 37.3%. The two groups differed at an insignificant level in the incidence of postoperative anemia.

Table 3 lists the patient demographic and clinical data that potentially affect hidden blood loss including sex, age, BMI, operation time and concomitant disease. Male and female patients presented no

differences in the hidden loss ($P = 0.171$). Moreover, the difference in BMI was found to pose no significant influence on the hidden loss ($P = 0.795$). When the relationship of the hidden loss with age, operation time and concomitant disease as independent factors was examined, significant influences of age, operation time and concomitant disease on the hidden blood loss ($P < 0.05$)

Table 3
Related factors affecting occult blood loss

Indicators		Number	HBL(ml)	P
Sex	Male	57	319 ± 250	0.171
	Famle	47	257 ± 199	
Age	< 60	35	227 ± 133	0.047
	> 60	69	317 ± 245	
BMI	< 24Kg/m2	57	296 ± 239	0.795
	> 24Kg/m2	47	285 ± 180	
Operation time	< 2h	25	237 ± 193	0.042
	≥ 2 h, < 3h	59	286 ± 173	
	≥ 3h	20	378 ± 256	
Concomitant disease	No	58	244 ± 151	0.01
	Yes	46	351 ± 253	

Table 4 lists the comparison result of functional recovery between the two groups, showing no significant difference in JOA score and ODI index and an significant influence of anemia on them one month after the operation (both $P < 0.05$).

Table 4.1
Comparison of JOA score and ODI index between the two groups one month after operation

	CBT-TLIF group	PS-TLIF group	P
Number	45	59	
JOA score	21.3±4.6	20.7±3.9	0.473
ODI score	22.5±3.4	23.1±3.3	0.368

Table 4.2

Comparison of JOA score and ODI index one month after operation with or without anemia

	No Postoperative anemia	Postoperative anemia	P
Number	65	39	
JOA score	21.7±3.7	19.6±4.8	0.014
ODI score	22.2±3.3	23.9±4.0	0.022

4 Discussion

Over the past few decades, Pedicle screw (PS) fixation has become the most classic and commonly used internal fixation method in spinal surgery [15]. Nonetheless, traditional pedicle screws are subject to some defects, such as the exposure of the lateral facet joint, longer surgical incision and extensive muscle peeling, which tend to cause postoperative anemia [16]. To overcome the above limitations, a new pedicle screw implantation technique with better biomechanical strength and performance, cortical bone trajectory (CBT), which was proposed by Santoni et al [8]. As stated by Karataglis et al., the entry point of CBT is more inward, requires no exposure of facet joints and transverse process, and reduces soft tissue peeling [17]. In addition, by placing nails from the bottom up in the sagittal plane, the surgical incision can be shortened by the traditional pedicle technique, thus greatly reducing intraoperative bleeding [8]. Despite the advantages of CBT technique such as short incision, less trauma and less intraoperative bleeding, the present research obtained the average perioperative total blood loss of CBT-TLIF patients at 603 ± 232 ml and the Hb loss of 18.3 ± 7.2 g/ml, higher than the expectation of spinal surgeons. Specifically, the HBL was 280 ± 227 ml, occupying 46.4% of the total blood loss, and the recessive blood loss was almost half of it after CBT-TLIF. Hence, recessive blood loss is concluded as a potentially major cause of the higher-than-expected blood loss for CBT-TLIF patients.

Concerning the specific factors of HBL caused by perioperative CBT-TLIF, the analysis is as follows: (1) Age: at present, advanced age is widely accepted by domestic and foreign scholars as an important factor affecting the amount of HBL. In this research, patients aged over 60 displayed significantly higher recessive blood loss than patients aged no more than 60, showing a statistical significance. CBT technology is often applied to elderly patients with osteoporosis because of its good biomechanical properties, which may lead to more HBL. (2) The time of operation: it is generally believed that longer operation time leads to longer tissue exposure time, which means more hidden blood loss during the operation. Here, it was found that the patients with operation time more than 3 h had more HBL than those with less than 2 h, showing a statistical difference; therefore, the operation time was considered a factor influencing HBL in the CBT group. (3) The bleeding surface of the cancellous bone: the CBT nail placement point is the intersection of the vertical line of the center of the superior articular process and the 1mm horizontal line below the inferior edge of the transverse process. It is located on the outside of the isthmus, where the bone is relatively hard. Most of the patients with lumbar degeneration suffer from

serious osteophyte hyperplasia, and a grinding drill is often needed to remove part of the cortical bone and part of the upper and lower lamina during the operation, and to thoroughly scrape the cartilage endplate for promoting interbody fusion. This will expose a large area of the cancellous bone surface, resulting in slow postoperative bleeding. (4) Venous plexus injury: it is easy to injure the intraspinal venous plexus during intraspinal decompression, which may impede the process of stopping bleeding. (5) Rehydration: after blood loss, thrombocytopenia occurs in the body. Rehydration after coagulation factors is diluted and the blood coagulation function is decreased, making it easier to ooze blood after the operation.

In conclusion, for the patients with CBT screw for lumbar fusion, the small incision, less muscle peeling and relatively less dominant blood loss lead to the speculation of the small blood loss of patients after CBT-TLIF. However, it was found that the recessive blood loss of patients after CBT-TLIF was not less than that of traditional pedicle screw fixation, accounting for almost 1 / 2 of the total blood loss. Therefore, the postoperative blood loss of patients is more likely to be ignored, resulting in postoperative anemia and covering up the causes of anemia. This will reduce the opportunity of postoperative rehabilitation, prolong the length of stay of patients, and even endanger the life of patients. Therefore, for the patients with CBT screw internal fixation, we should actively evaluate the factors affecting postoperative occult blood loss before the operation. Other strategies are also needed, such as taking further preventive measures for high-risk patients, stopping bleeding during the operation, shortening the time of operation, paying close attention to recessive blood loss after the operation, and reexamining blood routine in time to supplement blood volume.

Still, some limitations exist in the present study. First of all, all patients were from one institution, bringing a potential risk of bias. Second, the sample size was insufficient. Therefore, more samples are needed for further study. Third, the results of this retrospective study are not convincing enough and the level of evidence is insufficient. Therefore, a prospective randomized controlled study on the application of CBT in lumbar surgery is needed.

Declarations

Ethics approval and consent to participate

This paper has received ethical approval from the Institutional Review Board of The Second Affiliated Hospital and Y uying Children' s Hospital of Wenzhou Medical University.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request

Competing interests

The authors proclaim no competing interests.

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Authors' contributions

XLH and CYW analysis and interpretation of data and wrote the manuscript. CX and KLZ helped to conceive of and design the trial. XBL helped to conceive the trial and revised the manuscript. CQJ and YLC critically revising the article. HJZ and HHS prepared figures. WFN helped to conceive and design the study and critically revised the manuscript. All authors read and approved the final manuscript.

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Figures

1A.

1B.

Figure 1

1A. CBT screw procedure 1B. PS screw procedure