

Analysis of risk factors for perioperative hidden blood loss in patients undergoing transforaminal lumbar interbody fusion

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Abstract

Objective: This study was performed to analyze the correlation between perioperative hidden blood loss (HBL) and the general condition of patients undergoing transforaminal lumbar interbody fusion (TLIF).

Methods: We retrospectively analyzed patients who underwent TLIF from July 2017 to July 2019 in our hospital. Sex, age, body mass index, underlying diseases, American Society of Anesthesiologists classification, coagulation function, preoperative and postoperative hemoglobin level and hematocrit, surgery time, fusion level, intraoperative blood loss, and drainage volume were recorded. Postoperative complications were also recorded. The amount of HBL was calculated, and its correlation with related variables was analyzed.

Results: The mean surgery time was 153.32 ± 54.86 minutes. The total perioperative blood loss was 789.22 ± 499.68 mL, including HBL of 315.69 ± 199.87 mL. Pearson correlation analysis showed statistically significant differences in HBL according to the body mass index, hypertension, fibrinogen, surgery time, and fusion level. Multiple linear regression analysis indicated that the surgery time and fusion level were independent risk factors for HBL.

Conclusions: A certain amount of HBL occurs in TLIF surgery and cannot be ignored in daily clinical work. The operation time and surgery level are independent risk factors for HBL.

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Keywords

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Introduction

With the growth in the size of the aging population, the incidence of lumbar disc herniation, spinal stenosis, spondylolisthesis, and other lumbar degenerative diseases (LDDs) has increased. LDDs significantly affect patients' quality of life and are associated with higher pain scores and reduced function.¹ Severe cases of LDD or failed conservative treatment of LDD usually requires surgical intervention. Lumbar interbody fusion is a well-established surgical procedure that involves placing an implant within the intervertebral space after discectomy.²

Transforaminal lumbar interbody fusion (TLIF), a modified lumbar interbody fusion technique, was first described by Harms and Rolinger³ in 1982 and became popular in 1998.⁴ TLIF achieves 360° circumferential fusion via a posterolateral approach with a lower risk of central neurological injury. Because TLIF involves extensive muscle retraction and dissection, postoperative anemia requiring extra transfusion often occurs.⁵ Postoperative anemia often causes related complications, thereby extending the duration of hospitalization and increasing the physiological, psychological, and economic burdens on patients. However, several surgeons have found that perioperative reduction of the hemoglobin (Hb) level did not match the visible blood loss during surgery.

The concept of hidden blood loss (HBL) was introduced by Sehat et al.⁶ in a study evaluating the total blood loss after total

knee arthroplasty. Moreover, HBL has been widely investigated in hip fracture repair,⁷ total joint arthroplasty,⁸ and spine surgery.⁹ To the best of our knowledge, relatively few studies have focused on the risk factors for HBL in patients undergoing TLIF. We conducted a retrospective study in which we collected the clinical data of patients who underwent TLIF in our hospital, calculated the HBL, and analyzed the risk factors for TLIF.

Materials and methods

Patients

From July 2017 to July 2019, 201 patients underwent lumbar fusion surgery for lumbar disc herniation, lumbar spinal stenosis, lumbar spondylolisthesis, and other LDDs. The inclusion criteria were diagnosis of an LDD with surgical indications; no liver or kidney dysfunction, bleeding embolism, or blood system-related diseases; treatment by TLIF; first-time lumbar surgery; complete relevant medical data; and performance of TLIF by the same group of surgeons. The exclusion criteria were lumbar revision surgery; lumbar infection, tuberculosis, or tumor; scoliosis, ankylosing spondylitis, or other spinal deformities; intraoperative cerebrospinal fluid leakage; and an American Society of Anesthesiologists (ASA) classification level of IV. We recruited 94 patients based on the aforementioned criteria. This study was approved by the ethics committee of our

hospital (No. 2019-02), and written informed consent was obtained from each patient before surgery.

Surgical technique

All surgeries were performed by the same experienced surgeon (F.X.). After induction of general anesthesia, C-arm fluoroscopy was performed to confirm the fusion segments. A midline posterior incision was made, and the tissue was then peeled along the spinous process of the vertebral periosteum, exposing the lamina and facet joints. Pedicle screws were implanted according to the conventional method. Fusion segments adjacent to the vertebral facet were resected, the lateral recess was expanded, the yellow ligament was resected, and the nerve root was exposed and carefully protected. The annulus was cut, and the nucleus and endplate cartilage were scraped. The cage was implanted after conventional bone grafting. After fluoroscopic examination to determine adequate positioning of the pedicle screw and cage, a negative-pressure drainage tube was placed, and the absence of a bleeding point was confirmed before the incision was sutured. Intravenous antibiotics were used for 24 hours after surgery to prevent perioperative infection. The drainage tube was removed when the patient's routine drainage fluid volume was <50 mL in 24 hours.

Data extraction

Demographic information such as sex, age, body mass index (BMI), underlying diseases (hypertension, diabetes mellitus), and disease group (lumbar disc herniation, lumbar stenosis, lumbar spondylolisthesis) were recorded by resident doctors when the patients were hospitalized. Routine blood tests and coagulation function examinations were completed before the surgery,

normally on preoperative day 1. The hematocrit (Hct), Hb level, prothrombin time, activated partial thromboplastin time, and fibrinogen level were then collected. During the surgery, an experienced anesthetist (Z.Q.Y.) assessed and recorded the patients' ASA classification, surgery time, surgical blood loss, and transfused blood units. The surgery fusion levels and segments were written in the operation notes. The Hct and Hb level were measured again on postoperative day 3. The total postoperative drainage volume and postoperative transfusion units were measured by a spinal nurse.

Postoperative complications were also recorded, including wound disruption, deep surgical site infection, pneumonia, urinary tract infection, delirium, spinal epidural hematoma formation, acute renal failure, acute heart failure, deep venous thrombosis, and pulmonary embolism.

Calculation of HBL

Nadler's formulas¹⁰ were used to calculate the blood volume, visible blood loss, and HBL as follows:

$$\text{Blood volume (L)} = K1 \times \text{height (m)}^3 + K2 \times \text{weight (kg)} + K3$$

For men, $K1 = 0.3669$, $K2 = 0.03219$, and $K3 = 0.6041$; for women, $K1 = 0.3561$, $K2 = 0.03308$, and $K3 = 0.1833$.

$$\text{Total blood loss (L)} = \text{blood volume} \times (\text{Hct}_{\text{preop}} - \text{Hct}_{\text{postop}})$$

$\text{Hct}_{\text{preop}}$ was defined as the Hct on preoperative day 1, and $\text{Hct}_{\text{postop}}$ was defined as the Hct on postoperative day 3.

$$\text{Visible blood loss (L)} = (\text{surgical blood loss} + \text{postoperative drainage}) \times [(\text{Hct}_{\text{preop}} - \text{Hct}_{\text{postop}}) / 2]$$

HBL (L) = total blood loss – visible blood loss + transfused blood

Statistical analysis

The data were analyzed using SPSS v22.0 for Mac (IBM Corp., Armonk, NY, USA). Descriptive data are presented as mean \pm standard deviation or number and percentage of cases. Pearson correlation analysis and multivariate linear regression analysis were performed to identify risk factors for HBL. A *P*-value of <0.05 was considered statistically significant.

Results

The study group comprised 46 men and 48 women ranging in age from 44 to 79 years. Their mean BMI was 22.6 ± 2.3 kg/m². With respect to disease group, 44 patients had lumbar disc herniation, 31 had lumbar stenosis, and 19 had lumbar spondylolisthesis. With respect to the fusion level, 12 patients had disease at the L3–L4 level, 45 at the L4–L5 level, and 47 at the L5–S1 level (some patients underwent multiple-segment fusion surgery). The mean preoperative Hb level and Hct were 135 ± 12 g/L and 0.417 ± 0.028 , respectively. Coagulation function testing showed that the mean prothrombin time, activated partial thromboplastin time, and fibrinogen level were 10.8 ± 0.6 s, 27.1 ± 2.9 s, and 2.9 ± 0.8 g/dL, respectively. In terms of the ASA classification, 28, 40, and 26 patients had a physical status classification of I, II, and III, respectively. The mean surgery time was 153.32 ± 54.86 minutes. The mean total blood loss was 789.22 ± 499.68 mL. The mean visible blood loss was 473.53 ± 299.81 mL. The mean HBL was 315.69 ± 199.87 mL, which accounted for 40.17% of the total blood loss (Table 1).

Pearson correlation analysis showed that the following parameters were statistically

Table 1. Patient demographics.

| Parameters | Statistics |
|-----------------------------|---------------------|
| Total patients | 94 |
| Sex | |
| Male | 46 |
| Female | 48 |
| Disease groups | |
| Lumbar disc herniation | 44 |
| Lumbar stenosis | 31 |
| Lumbar spondylolisthesis | 19 |
| Fusion level | |
| L3–L4 | 12 |
| L4–L5 | 45 |
| L5–S1 | 47 |
| ASA classification | |
| Level I | 28 |
| Level II | 40 |
| Level III | 26 |
| Age, years | 57.5 (44–79) |
| Mean BMI, kg/m ² | 22.6 ± 2.3 |
| Mean surgery time, minutes | 153.32 ± 54.86 |
| Mean total blood loss, mL | 789.22 ± 499.68 |
| Mean visible blood loss, mL | 473.53 ± 299.81 |
| Mean HBL, mL | 315.69 ± 199.87 |
| Preoperative Hb, g/L | 135 ± 12 |
| Preoperative Hct | 0.417 ± 0.028 |
| PT, s | 10.8 ± 0.6 |
| APTT, s | 27.1 ± 2.9 |
| Fibrinogen, g/dL | 2.9 ± 0.8 |

Data are presented as n, median (range), or mean \pm standard deviation.

ASA, American Society of Anesthesiologists; BMI, body mass index; HBL, hidden blood loss; Hb, hemoglobin; Hct, hematocrit; PT, prothrombin time; APTT, activated partial thromboplastin time.

significant: BMI ($P = 0.006$), hypertension ($P = 0.004$), fibrinogen ($P < 0.001$), surgery time ($P < 0.001$), and fusion level ($P < 0.001$) (Table 2). The surgery time ($P < 0.001$) and fusion level ($P < 0.001$) were independent risk factors for HBL according to the multivariate linear regression analysis (Table 3).

Postoperative complications were documented in seven patients (7%), including wound disruption (one patient), deep

surgical site infection (two patients), pneumonia (two patients), urinary tract infection (one patient), and a spinal epidural hematoma (one patient).

Table 2. Results of Pearson correlation analysis.

| Parameters | Sig (two-tailed) | P |
|-----------------------------|---------------------|---------|
| Sex | 0.062 | 0.372 |
| Age | 0.054 | 0.625 |
| BMI | 0.201 | 0.006* |
| ASA classification | 0.103 | 0.079 |
| Underlying disease | | |
| Hypertension | 0.209 | 0.004* |
| Diabetes mellitus | 0.037 | 0.702 |
| Disease group | | |
| Lumbar disc herniation | 0.071 | 0.298 |
| Lumbar stenosis | 0.052 | 0.634 |
| Lumbar spondylolisthesis | 0.104 | 0.075 |
| Preoperative Hb | 0.105 | 0.070 |
| Preoperative Hct | 0.091 | 0.128 |
| PT | 0.097 | 0.105 |
| APTT | 0.077 | 0.244 |
| Fibrinogen | 0.482 | <0.001* |
| Surgery time | 0.521 | <0.001* |
| Fusion level | | |
| L3–L4 | 0.096 | 0.106 |
| L4–L5 | 0.107 | 0.069 |
| L5–S1 | 0.052 | 0.638 |
| Number of fusion levels | 0.593 | <0.001* |
| Postoperative complications | 0.214 | 0.003* |

* $P < 0.05$

BMI, body mass index; ASA, American Society of Anesthesiologists; Hb, hemoglobin; Hct, hematocrit; PT, prothrombin time; APTT, activated partial thromboplastin time.

Discussion

HBL refers to the unmeasurable blood loss in the perioperative period and does not include visible blood loss and the postoperative drainage volume. A large amount of HBL can exacerbate postoperative anemia, leading to higher risk of wound disruption, infection, and development of delirium and other complications. Thus, a correct understanding of HBL can ensure patient safety and improve postoperative rehabilitation. In recent years, investigation of perioperative HBL in spinal surgery has gained the attention of many researchers. Smorgick et al.¹¹ indicated that the HBL was 600 mL (42% of the total blood loss) in posterior spinal fusion. Ju and Hart¹² concluded that in anterior lumbar interbody fusion, the HBL averaged 39.2% of the total blood loss. In the present study, the mean HBL was 315.69 ± 199.87 mL, which accounted for 40.17% of the total blood loss and thus should not be ignored.

The pathomechanism of HBL is still controversial, and most investigators assume that it is related to activation of blood in the tissue space, hemolysis, and fibrinolytic system.^{13,14} Smith et al.¹⁵ reported that the HBL was higher in female than male patients with hip fractures. Madsen et al.¹⁶ stated that age, the ASA status, and the admission Hb level were independently associated with large blood loss volumes in patients admitted with a fractured hip. Yin et al.¹⁷ found that intraoperative

Table 3. Results of multivariate linear regression analysis.

| Parameters | β (Unstandardized) | β (Standardized) | t | P |
|-----------------------------|--------------------------|------------------------|-------|---------|
| BMI | 0.143 | 0.249 | 1.724 | 0.092 |
| Hypertension | 62.594 | 0.018 | 1.003 | 0.960 |
| Fibrinogen | 89.672 | 0.137 | 2.314 | 0.336 |
| Surgery time | 148.496 | 0.145 | 6.192 | <0.001* |
| Number of fusion levels | 153.605 | 0.112 | 5.734 | <0.001* |
| Postoperative complications | 59.241 | 0.012 | 0.007 | 0.944 |

* $P < 0.05$.

BMI, body mass index.

blood loss and total drainage were risk factors for high HBL in patients undergoing anterior cervical fusion. The present study showed that the patients' demographic data such as their BMI and ASA classification were not risk factors for HBL. Pearson correlation analysis showed significant differences in the HBL according to the BMI, hypertension, and fibrinogen level, while the multivariate linear regression analysis showed no significant differences. We attribute this discrepancy to the limited sample size.

Similar to the investigation of HBL in posterior lumbar fusion surgery by Wen et al.,¹⁸ our research indicated that the surgery time and fusion level were independent risk factors for perioperative HBL. The number of levels fused is reportedly a predictor of blood transfusion in spinal surgery.¹⁹ In addition, we considered that surgery involving multiple fusion levels enlarges the manipulation space and that implantation of more instruments facilitates movement of more red blood cells into the tissue space. In TLIF, we must cut the facet joints, open the lamina, remove the nucleus, and curettage the endplate of the vertebral body. When more levels are fused, the bleeding of the vertebral cancellous bone surface significantly increases.

The lumbar blood supply is abundant, and spinal venous plexus bleeding is particularly difficult to stop. Spinal surgeons usually use bipolar coagulation and gelatin sponges during surgery. Thus, an increased surgery time is associated with a larger amount of visible blood loss, which leads to high HBL.

By effectively reducing HBL, the occurrence of related complications can be decreased to a certain extent; this is conducive to early postoperative recovery and promotion of early exercise. Based on our research and clinical work, we have determined that the following measures should be implemented to reduce perioperative

HBL. (1) Actively control the intraoperative parameters, especially the blood pressure, liver and kidney function, and blood coagulation, to prevent complications. (2) Shorten the operation time as far as possible by improving the surgical methods or techniques, and reduce unnecessary surgical procedures. (3) Perform hemostasis during surgery. (4) Perform autologous blood transfusion if needed. Autologous blood transfusion is a safe and effective method to reduce visible blood loss during surgery by retransfusing the collected drainage blood, and it reduces perioperative transfusion rate. (5) Administer perioperative hemostatic drugs such as tranexamic acid²⁰⁻²² if no specific contraindications exist. The potential mechanism and advantage of the application of hemostatic drugs in reducing HBL involve direct targeting of the bleeding site immediately before wound closure after surgical hemostasis has been achieved. Inhibition of the local fibrinolytic activity helps to prevent fibrin clot dissolution and increases the clot volume and strength at the raw surgical surfaces, thus enhancing microvascular hemostasis.

Because our study was retrospective, it has several limitations. First, our sample size was small, resulting a high possibility of bias. Second, the general condition of the investigated patients who underwent TLIF was restrictive, and more parameters need to be included. Third, when we searched relative studies and references, we found no consistent opinion on when to remove the drainage tube. In our daily clinical work, we removed the drainage tube when the drainage volume was <50 mL in 24 hours. The point-in-time or evaluation criterion for removal of the drainage tube may disturb the outcome of HBL, and this deserves further investigation in future. Finally, because most of the patients were local residents, the influence of racial differences may have affected the research results.

Conclusions

A certain amount of HBL occurs in TLIF surgery and cannot be ignored in daily clinical work. A correct understanding of HBL can ensure patient safety and improve postoperative rehabilitation. The operation time and surgery level are independent risk factors for HBL. Our findings need to be validated in a multiple-center, multiple-parameter study involving a larger sample of patients.


Declaration of conflicting interest

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