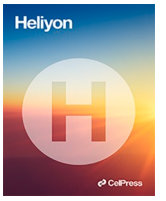
Heliyon 10 (2024) e33503

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Supplementary decompression and extended surgical time contribute to hidden blood loss In percutaneous endoscopic lumbar discectomy

Chong Chen [a,1], Wenlin Ye [a,1], Zhengran Yu [a], Xiaoqing Zheng [a], Jingxing Dai [b], Jun Ouyang [b], Dan Xiao [a,2,**], Yunbing Chang [a,2,*]

[a] Department of Spine Surgery, Guangdong Provincial People's Hospital (Guangdong Academy of Medical Sciences), Southern Medical University, Guangzhou, Guangdong, China

[b] Guangdong Provincial Key Laboratory of Medical Biomechanics & Guangdong Engineering Research Center for Translation of Medical 3D Printing Application & National Virtual & Reality Experimental Education Center for Medical Morphology & National Experimental Education Demonstration Center for Basic Medical Sciences & National Key Discipline of Human Anatomy, School of Basic Medical Sciences, Southern Medical University, Guangzhou, China

ARTICLE INFO

Keywords:
Hidden blood loss
Percutaneous endoscopic lumbar discectomy
Foraminal decompression
Influential factors
Multivariate linear regression analysis

ABSTRACT

Background: It is widely believed that the Percutaneous endoscopic lumbar discectomy (PELD) is associated with minimal blood loss. However, significant perioperative hidden blood loss (HBL) is frequently unaccounted for. This study aimed to investigate HBL and peri-operative factors contributing to HBL in a series of individuals undergoing PELD.

Method: ology: A total of 156 consecutive patients with a mean age of 43.6 years (ranging from 18 to 80 years) who underwent PELD at our department from May 2019 to November 2020, were included in the study. Factors including gender, age, body mass index, symptom duration, operation approach/technique, operation duration, the presence of associated chronic diseases, and improvements in the Visual Analog Scale (VAS) score, Japanese Orthopaedic Association (JOA) score and the Oswestry Disability Index (ODI) were analyzed, and Gross's formula was applied to calculate blood loss, which was used to determine HBL.

Results: The average total blood loss (TBL) was 221.0 ± 126.2 mL, while the average HBL was 181.7 ± 119.0 mL (82.2 % of TBL). There was no statistically significant difference in HBL between the transverse surgical approach and the interlayer approach. Additionally, no significant differences were observed in improvements in VAS, JOA, and ODI scores between the two surgical approaches. However, the multivariate linear regression analysis revealed that longer surgical time and foraminal decompression were factors contributing to the increase in HBL, which subsequently led to the occurrence of post-operative anemia.

Conclusion: HBL is significant in PELD cases with long surgical time and lumbar foraminal decompression.

* Corresponding author. Department of Spine Surgery, Guangdong Provincial People's Hospital (Guangdong Academy of Medical Sciences), Southern Medical University, No. 106, Zhongshan 2nd Rd, Guangzhou, Guangdong, 510080, China.

** Corresponding author. Department of Spine Surgery, Guangdong Provincial People's Hospital (Guangdong Academy of Medical Sciences), Southern Medical University, No. 106, Zhongshan 2nd Rd, Guangzhou, Guangdong, 510080, China.

E-mail addresses: orthodan@163.com (D. Xiao), changyunbing@gdph.org.cn (Y. Chang).

[1] Chong Chen and Wenlin Ye are co-first authors.

[2] Yunbing Chang and Dan Xiao contributed are corresponding authors.

https://doi.org/10.1016/j.heliyon.2024.e33503
Received 5 April 2024; Received in revised form 12 June 2024; Accepted 21 June 2024
Available online 22 June 2024

Abbreviations

HBL:	hidden blood loss
BMI:	body mass index
Hct:	hematocrit
PELD:	percutaneous endoscopic lumbar discectomy
LDH:	lumber disc herniation
LSS:	lumbar spinal stenosis
Hb:	hemoglobin
NSAIDs:	non-steroidal anti-inflammatory drugs
VAS:	visual analog scale
JOA:	Japanese Orthopedic Association
ODI:	Oswestry disability index
TBL:	total blood loss
PBV:	patient blood volume
VBL:	visible blood loss

1. Introduction

The consideration of hidden blood loss (HBL) in surgical operations was not a common practice until the development of a mathematical model by Brecher et al. [1]. Based upon the model, which incorporates various parameters such as blood volume, transfused red blood cells, hematocrit (Hct) levels before surgery and at discharge, volume of salvaged blood transfused during the procedure, and extent of intraoperative hemodilution. By utilizing this model, it was determined that the average volumes of blood loss for all surgeries were found to be twice as high as those estimated using the traditional approach.

It has been reported that hemorrhagic blood loss accounts for 40–49 % of the total blood loss in different orthopedic procedures [2,3], occurring more commonly and more significantly in patients who undergo multi-level posterior lumber fusion surgery for degeneration [4,5] and in those with rheumatoid arthritis who have posterior lumbar interbody fusion [6], respectively. Ogura et al. [7] quantitatively analyzed the amount of HBL in their study, which was calculated to range from 678 to 1267 mL in two- or three-level posterior lumbar decompression and fusion. From these findings, the amount of HBL during different orthopedic procedures has been clinically underestimated.

Percutaneous endoscopic lumbar discectomy (PELD) is a minimally invasive surgical technique utilized for the treatment of lumbar disc herniation (LDH) and certain forms of lumbar spinal stenosis (LSS) [8]. In comparison to alternative surgical methods, PELD offers numerous benefits [9–12], such as reduced intraoperative bleeding [13]. Several studies have suggested that the HBL in such minimally invasive spinal surgeries should not be ignored [14,15]. HBL could result in adverse effects on the prognosis of disease by increasing the incidence of various complications, which also might contribute to delayed wound healing, increased risk of infection and prolonged postoperative rehabilitation [16,17].

To date, the amount of HBL in PELD and the underlying risk factors have not been reported. A clear understanding of HBL during PELD and its causes will be valuable for improving this technique and its clinical outcomes. Therefore, we conducted this retrospective cohort study on a group of patients who underwent PELD at our institution to explore the potential occurrence of HBL and identify any associated risk factors that may contribute to heightened bleeding in PELD.

2. Methodology

The study followed a sample-of-convenience design to include all patients who were selected based upon inclusion/exclusion criteria, and the protocol for this study was reviewed and approved by the Ethics Committee of Guangdong Provincial People's Hospital (No. GDREC2020191H). Written informed consent was waived. Following the protocol, a total of 323 patients were identified who underwent surgical treatment by PELD between May 2019 and November 2020 and met the inclusion criteria of age older than 18 years with degenerative lumbar spine either from lumbar stenosis or lumbar disc herniation. Patients were excluded according to previous studies [18–22], if they had: 1) hematological diseases; 2) previous lumber surgery or trauma and transfusion history including blood products and crystalloids; 3) abnormal blood coagulation indexes or use of antiplatelet and anticoagulant drugs or herbal medications within 1 week of surgery; 4) abuse of tobacco ($\geq$20 cigarettes/day), alcohol (liquor $\geq$90 mL/day or 150 mL/week), or recreational drugs; and 5) current menstruation.

The information of gender, age, weight, height, body mass index (BMI), Hct levels, hemoglobin (Hb) levels pre- and post-operation, the operative segments, the surgical techniques, and comorbidities such as hypertension, rheumatoid arthritis and diabetes mellitus were conducted from the electronic medical records for comprehensive analysis. Additionally, the duration and features of symptoms prior to the operation were documented.

Prior to undergoing surgical therapy, all patients in the study had previously received non-surgical interventions or medications, such as functional exercise, non-steroidal anti-inflammatory drugs (NSAIDs), and vitamins B1 and B12, at local or community hospitals to address their ongoing symptoms that were impacting their daily lives. Two rheumatoid arthritis patients in our cohort stopped

steroid use before PELD. Back and leg pain as well as improvements in daily function were assessed by comparing Visual Analog Scale (VAS), Japanese Orthopaedic Association (JOA), and Oswestry Disability Index (ODI) scores on postoperative day one to preoperative values. No antibiotics were administered during the peri-operative period.

All PELD surgeries were performed by experienced surgeons. The surgery was performed with the patient lying in a prone position on a carbon-fiber operating bed, so that X-ray images could be taken during the surgery.

An incision approximately 8 mm long was made in the skin. Then through the guide needle, a working channel was inserted into the posterior wall of the spinal canal along with an expansion cannula, through which the operating system was deployed. The endoscopy allowed visualization of various structures within the spinal canal, including the epidural fat, nerve root, disc flavum ligament space, herniated disc tissue, and other relevant components. A typical case was presented in Fig. 1. Simple discectomy, along with percutaneous endoscopic lumbar foraminoplasty or percutaneous endoscopic ventral facetectomy if necessary, was performed using a high-speed drill (Fig. 2) and/or trephine reamer (Fig. 3) for patients with foraminal or lateral recess stenosis undergoing LSS treatment [23, 24]. Hemostasis was achieved using the bipolar technique, after which the channel and light source were slowly removed. The skin incision was then sutured with one stitch. Throughout the surgery, the core body temperature was monitored and maintained within the normal range.

Intraoperatively, the patients underwent resuscitation with a 500 mL sodium lactate Ringer's injection. In cases where the duration of the operation exceeded 2 h, a 500-mL hydroxyethyl starch injection was administered.

Patients were routinely scheduled to have complete blood count analysis, including Hct before the operation and on postoperative day one. Because all patients remained hemodynamically stable and did not have possible further fluid shifts on postoperative day one, this day was chosen. Anemia was diagnosed based on Hb levels (<120 g/L for females and <130 g/L for men) [25]. On postoperative day one, we regularly resuscitated the patients with another 500-mL crystalloid injection, and oral NSAIDs and vitamin B_1/B_{12} were given postoperatively. Patients were normally discharged in one or two days after the surgery.

The total patient's blood volume (PBV) was calculated with the following equation [26]: $PBV = k1 \times \text{height (m)}^3 + k2 \times \text{weight (kg)} + k3$. For male patients, $k1 = 0.3669$, $k2 = 0.03219$, and $k3 = 0.6041$, while for female patients, $k1 = 0.3561$, $k2 = 0.03308$, and $k3 = 0.1833$. The equation was applied to quantitively determine the total blood loss (TBL) in the perioperative period as [27]: $TBL = PBV \times (Hct_{pre} - Hct_{post})/Hct_{ave}$, where Hct_{pre} is designated to be the preoperative Hct level, Hct_{post} is the Hct level on postoperative day one, and Hct_{ave} is the average of the Hct_{pre} and Hct_{post} levels. Due to the absence of a blood transfusion, no drainage was placed. Additionally, visible blood loss (VBL) represents the recorded intraoperative bleeding, and HBL was defined as HBL (mL) = TBL−VBL.

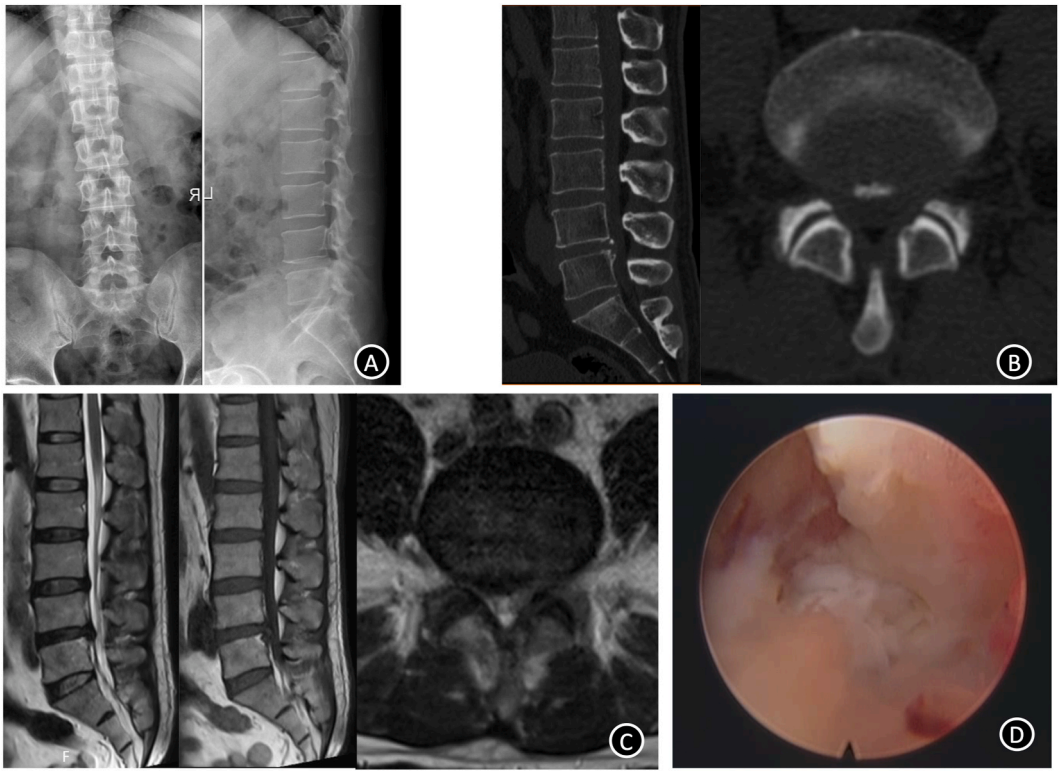


Fig. 1. A 46-year-old male patient who underwent PELD (L4/L5) for LDH. (A) X-ray images of lumbar vertebrae at anteroposterior and lateral positions. (B) Computed tomography sagittal (left) and axial (right) images indicating intervertebral disc calcification in L4/5. (C) T2-weighted sagittal (left), T1 weighted sagittal (middle) and axial (right) preoperative magnetic resonance images of the lumbar spine showing L4/5 disc herniation. (D) Simply discectomy for herniated disc under PELD.

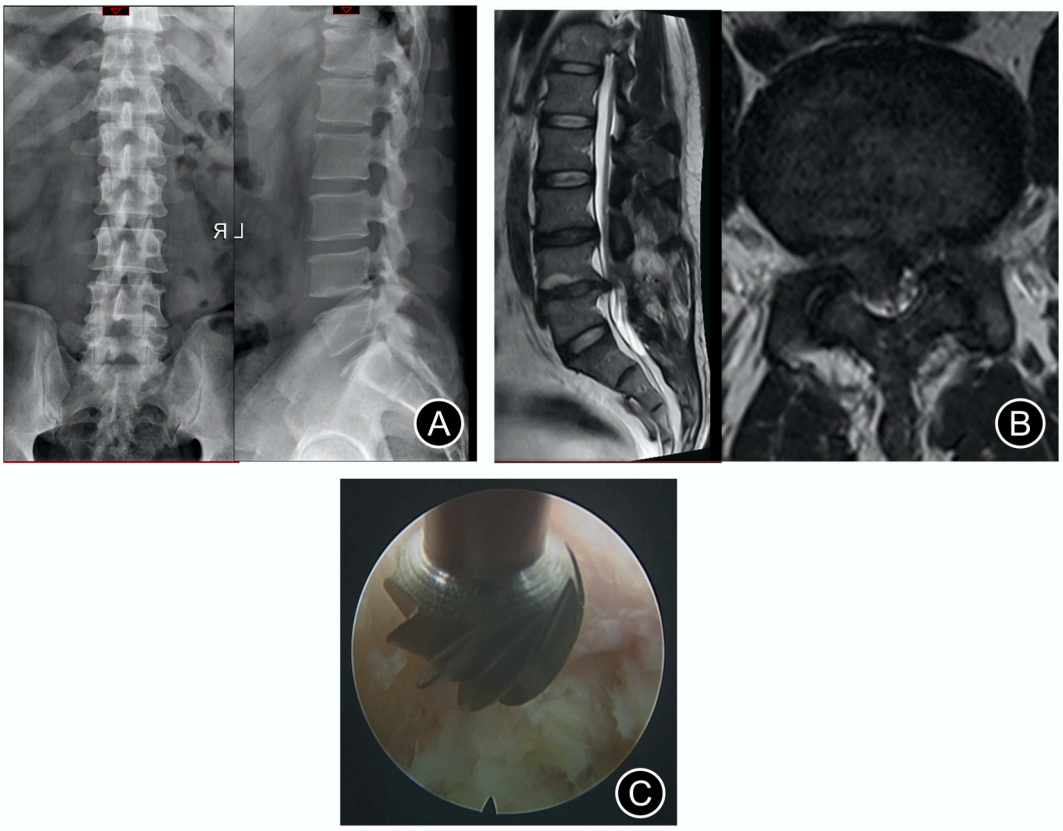


Fig. 2. Imaging results for a 48-year-old male patient who underwent PELD (L4/L5) for LDH and LSS. (A) X-ray images of lumbar vertebrae at anteroposterior and lateral positions. (B) T2-weighted sagittal (left) and axial (right) preoperative magnetic resonance images of the lumbar spine showing L4/5 disc herniation and secondary foramen stenosis. (C) Foraminoplasty was performed via high-speed drilling.

During the procedure, the operation table was covered with tarps, and all the blood-water mixture was recovered during the procedure. The gauze used during the procedure was also weighed to calculate the volume of fluid vacuum aspirator. The VBL could be calculated by adding the volume of the blood-water mixture in the above-mentioned recovery bag and the volume of the gauze suction solution and subtracting the volume of the flushing saline solution used during the operation [28].

The statistical software SPSS version 23.0 (SPSS, Inc, Chicago, IL, USA) was employed for conducting all statistical analyses. Independent-samples Student's t-tests were utilized to assess differences based on sex or surgical approach. The Chi-square test was employed to identify differences in anemic status before and after surgery. Additionally, the Pearson or Spearman method was employed to examine any potential correlation with Hb levels. A correlation analysis was performed to investigate the relationship between four quantitative variables (age, BMI, surgical time, duration of symptoms) and seven qualitative variables (gender, surgical approach, symptomatic side, decompression procedures, hypertension, rheumatoid arthritis, and diabetes mellitus) in order to identify the independent factors contributing to HBL during the peri-operative period. Statistical significance was determined by P values < 0.05.

3. Results

The demographic and clinical attributes of these patients are outlined in Table 1. The age of the selected patients ranged from 18 to 80 years, with a mean age of 43.6 years. The duration of their symptoms varied from 6 to 55 months, with a mean duration of 23.1 $\pm$ 12.2 months.

The calculated decreasing percentiles in Hct, Hb loss, duration of symptoms, and HBL are presented in Table 1. The mean TBL was 221.0 $\pm$ 126.2 mL, and the mean VBL was 39.3 $\pm$ 11.8 mL. Thus, the mean HBL was 181.7 $\pm$ 119.0 mL (82.22 % of TBL). The mean HBL did not significantly differ between male and female patients (193.3 $\pm$ 125.8 mL vs 162.8 $\pm$ 103.6 mL, P = 0.196). And the mean HBL for PELD with the lateral approach (L4/5) was no significantly different for PELD with the interlaminar approach (L5/S1) (186.0 $\pm$ 117.8 mL vs 175.0 $\pm$ 120.7 mL, P = 0.545). Furthermore, various parameters were compared between the groups of patients with the first and last 25th percentiles of HBL (Table 2). In addition to the changes in HBL, Hb and Hct, the surgical approach, surgical time and decompression procedure of the 25th percentile cases ($P < 0.05$) were significantly different from those of the 75th percentile cases.

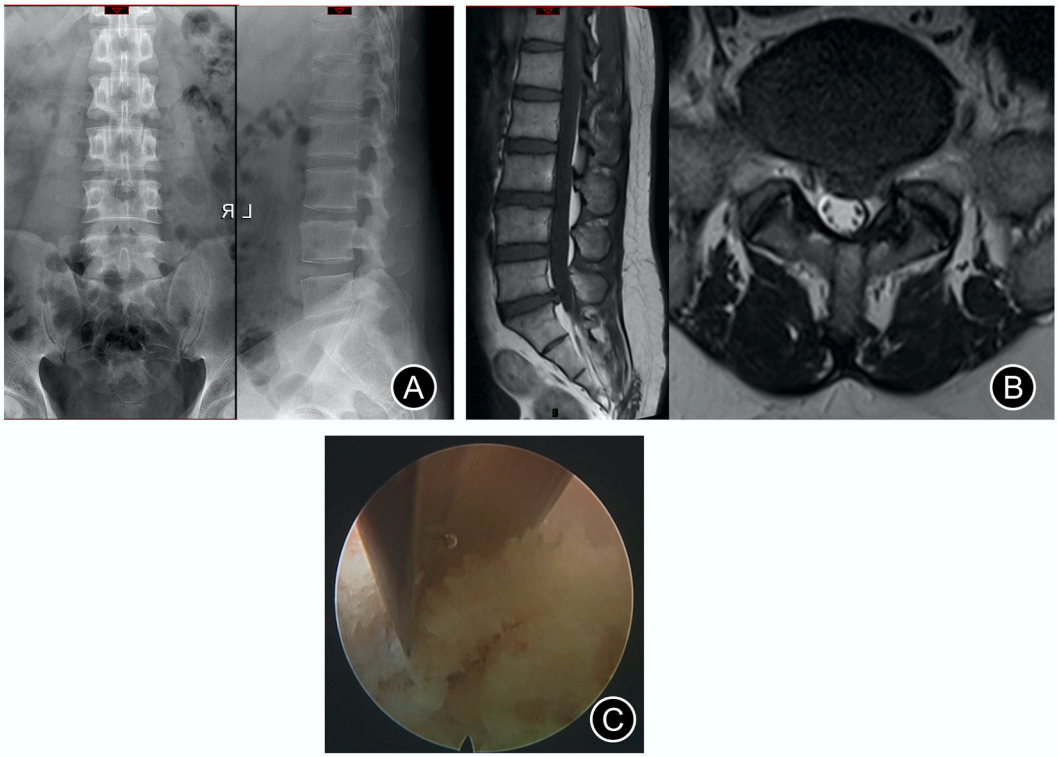


Fig. 3. Imaging results for a 42-year-old male patient who underwent PELD (L5/S1). (A) X-ray images of lumbar vertebrae at anteroposterior and lateral positions showing L5/S1 disc herniation. (B) T1-weighted sagittal (left) and T2-weighted axial (right) preoperative magnetic resonance images of the lumbar spine showing L5/S1 disc herniation. (C) Partial ventral facetectomy was performed using a trephine reamer.

Table 1
Patient's demographic information.

Parameters	Males	Females	L4/5	L5/S1	Total
Number of patients	98	58	98	58	156
Age (years)	40.9 ± 10.2	47.5 ± 12.0	43.8 ± 11.9	42.6 ± 10.34	43.6 ± 12.0
BMI (kg/m^2)	23.5 ± 3.1	22.6 ± 2.8	23.0 ± 3.2	23.3 ± 2.7	23.4 ± 3.4
Hct level loss (%)	5.2 ± 2.8	5.2 ± 2.8	5.4 ± 2.8	4.8 ± 2.8	5.2 ± 2.8
Hb level loss (%)	6.7 ± 3.7	6.7 ± 4.5	6.8 ± 4.0	6.5 ± 4.0	6.7 ± 4.0
Hb loss (g/L)	10.0 ± 6.0	8.7 ± 5.8	9.6 ± 6.1	9.4 ± 5.8	9.5 ± 6.0
Duration of symptom (months)	21.8 ± 11.6	25.5 ± 12.8	24.8 ± 13.0	20.3 ± 10.2	23.1 ± 12.2
Surgical time (min)	99.5 ± 28.3	92.4 ± 24.7	101.3 ± 26.3	89.3 ± 28.3	92.2 ± 26.9
TBL (mL)	234.2 ± 133.3	199.4 ± 109.9	229.1 ± 123.9	208.0 ± 129.2	221.0 ± 126.2
VBL (mL)	40.9 ± 12.6	36.7 ± 9.8	43.1 ± 10.1	33.0 ± 11.7	39.3 ± 11.8
HBL (mL)	193.3 ± 125.8	162.8 ± 103.6	186.0 ± 117.8	175.0 ± 120.7	181.7 ± 119.0

BMI, body mass index; Hct hematocrit; Hb, hemoglobin; TBL, total blood loss; VBL, visible blood loss; HBL, hidden blood loss.

There were no statistically significant differences (all $P > 0.05$) observed in the VAS score (3.51 vs 3.45), JOA score (17.70 % vs 16.83 %), or ODI (37.68 % vs 38.28 %) improvements between the two surgical types, as shown in Table 3. Additionally, none of the patients in this cohort received any form of blood products or required wound drainage, and no postoperative complications were observed.

4. Contributing factors to HBL

HBL increased proportionately with increasing surgical time ($R^2 = 0.631$, $P < 0.05$; Fig. 4). Additionally, postoperative anemia was observed in 32 patients, and a comparison of pre-operative and post-operative anemic status revealed a significant association between HBL and the incidence of postoperative anemia ($P < 0.001$, Chi-square test; Table 4). Further analysis demonstrated significant correlations between the increase in HBL and both surgical time ($P < 0.001$) and decompression ($P < 0.001$) (Table 5). Moreover, through the implementation of multivariable linear regression analysis, it was determined that prolonged surgical time ($P < 0.001$) and decompression ($P < 0.001$) were significant contributing factors to the incidence of HBL, as indicated in Table 6.

Table 2
Comparison of characteristics between patients in the 25th percentile and 75th percentile HBL groups.

	25th percentile HBL		75th percentile HBL		P
Surgical approach	Transforaminal	Interlaminar	Transforaminal	Interlaminar	<0.05[a]
Number of patients	29	10	19	20	
Gender	Male	Female	Male	Female	<0.05[a]
Number of patients	7	32	35	4	
Age (years)	44.3 ± 11.5		41.2 ± 9.4		0.19
BMI (kg/m^2)	21.5 ± 3.0		24.1 ± 2.5		<0.05[a]
Hct level loss (%)	5.2 ± 2.5		6.7 ± 2.9		<0.05[a]
Hb level loss (%)	6.2 ± 4.1		8.6 ± 3.4		<0.05[a]
Hb loss (g/L)	7.6 ± 5.0		13.8 ± 5.8		<0.05[a]
Duration of symptom (months)	25.0 ± 12.1		23.1 ± 12.2		0.51
Surgical time (min)	91.4 ± 24.4		113.4 ± 27.8		<0.05[a]
Decompression	19		28		<0.05[a]
HBL (mL)	158.1 ± 88.0		263.2 ± 127.0		<0.05[a]

[a] $P < 0.05$; HBL, hidden blood loss; BMI, body mass index; Hct hematocrit; Hb, hemoglobin.

Table 3
Comparison of score improvements between the two surgical approaches.

	interlaminar approach	transforaminal approach	P
Visual Analog Scale (VAS)	3.51 ± 0.94	3.45 ± 0.63	0.361
Japanese Orthopaedic Association (JOA)	17.70 ± 4.50	16.83 ± 0.55	0.511
Oswestry Disability Index (ODI)	37.68 ± 11.71	38.28 ± 9.86	0.725

5. Discussion

The concept of percutaneous posterolateral nucleotomy was first introduced in 1973, and subsequently, PELD was utilized for the treatment of lumbar disc herniation [29]. PELD encompasses both percutaneous endoscopic transforaminal discectomy and percutaneous endoscopic interlaminar discectomy. PELD has gained significant popularity as a minimally invasive spinal procedure due to its small incision, rapid recovery, short hospital stay, and comparable clinical outcomes to open surgery [30]. It has been widely accepted that PELD is associated with minimal blood loss, as supported by intraoperative direct observation.

However, minimally invasive spinal procedures such as transforaminal lumbar interbody fusion might result in a significant amount of HBL [31]. The volume of hemorrhagic blood loss during transforaminal lumbar interbody fusion was 488.4 ± 294.0 mL, which accounted for 52.5 % of the TBL and the HBL volume was reported to be 469.5 ± 195.3 mL, representing 57.6 % of the TBL during unilateral biportal endoscopic surgery [18,32]. Significant HBL had been noticed in the care of PELD patients based upon the changes between pre- and postoperative Hct levels [33]. Despite the lack of understanding regarding the etiology of PELD-associated HBL, various potential origins of HBL in PELD have been suggested, such as hemolysis, blood leakage into adjacent tissues, presence of residual blood in a non-functional area, or mere underestimation of blood loss. Through a comparative analysis of cases with HBL volumes at the 25th and 75th percentiles, we have identified surgical duration and decompression procedure as potential contributing factors to the occurrence of perioperative HBL in these minimally invasive procedures.

The transforaminal or lateral approach has been commonly employed for the treatment of various types of herniated nucleus pulposus, with the exception of the intra-canalicular type at L5/S1 accompanied by a prominent iliac crest. In this particular study, a transforaminal approach was chosen for the treatment of L4/L5, while an interlaminar approach was selected for L5/S1. This decision was based on the premise that a transforaminal approach would necessitate the incision of a greater amount of muscle tissue, potentially leading to increased trauma. However, neither of the approaches yielded significant alterations in VAS, JOA, and ODI scores on the first day after surgery. Furthermore, the multivariable linear regression analysis conducted in this study failed to establish a correlation between the surgical approach in PELD and the quantity of HBL. Nevertheless, our investigation did reveal that the transforaminal approach resulted in approximately 11 mL more HBL compared to the interlaminar approach. Additionally, another study reported no noteworthy disparities in estimated blood loss, duration of postoperative bed rest, or length of hospital stay between percutaneous endoscopic transforaminal discectomy and percutaneous endoscopic interlaminar discectomy [34]. Therefore, convincing evidence is still needed to determine which approach is the better choice.

In our study, because the patients underwent PELD surgery without a drainage catheter, the TBL was equal to HBL plus VBL, and the Hct method provided an indicator to estimate HBL. Because we standardized the fluid volume administered in the perioperative period, the contribution of the intravenous fluid to the development of HBL can be disregarded. However, our study found 32 patients without a preoperative history of anemia or coagulation abnormalities suffered from anemia postoperatively, the extent of which did not correspond with the intraoperative VBL, indicating perioperative HBL was likely overlooked in the postoperative management of our patients.

Our analysis further revealed a positive correlation between increased HBL and increased surgical time. Greater soft tissue damage may have partially accounted for this correlation. Generally, the greatest sources of HBL during surgery have been considered to be

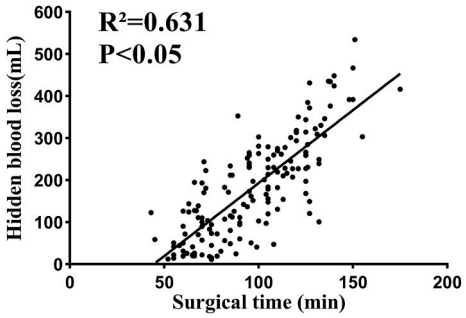


Fig. 4. HBL according to surgical time.

Table 4
Result of Chi-square test for anemia.

	Anemia	Non-Anemia	P
Pre-operation	13	143	
Post-operation	45	111	<0.001[a]

[a] $P < 0.001$.

Table 5
Results of correlation analysis for HBL.

Parameters	Sig (2-tailed)	P
Gender	−0.125	0.121
Age (years)	0.076	0.344
BMI (kg/m^2)	0.031	0.704
Duration of symptom (months)	0.003	0.975
Surgery		
Symptom side		
Surgical approach	−0.045	0.578
Decompression	0.756	<0.001[a]
Surgical time	0.794	<0.001[a]
Comorbid conditions		
Hypertension	0.000	1.000
Rheumatoid arthritis	−0.104	0.197
Diabetes mellitus	0.046	0.573

[a] $P < 0.001$; HBL, hidden blood loss; BMI, body mass index.

Table 6
Results of multiple linear regression method for HBL coefficients.

Coefficients	Unstandardized β	Standard error	Standardized β	T	P
Constant	−93.921	19.760		−4.753	<0.001[a]
Surgery					
Decompression	100.157	12.716	0.423	7.877	<0.001[a]
Surgical time	2.298	0.234	0.526	9.801	<0.001[a]

Dependent variable: HBL, hidden blood loss (mL).
[a] $P < 0.001$.

extravasation of blood from surgical sites into surrounding tissues and hemolysis [35,36]. In patients who receive treatment for LSS and undergo foraminoplasty or ventral facetectomy, high-speed drilling and/or trephine reamers might increase bone-derived bleeding. In the present study, we found that the application of decompression procedures was positively correlated with HBL.

The present study has several limitations. Firstly, the cohort size was relatively small, and the study lacked a control arm. Secondly, the data analysis was not based upon randomization or a blind study design. Thirdly, postoperative Hct and Hb levels were measured only on postoperative day one, and it would be ideal for these to be checked in the following postoperative day until returning to a normal level. Lastly, fluid shifts should be taken into consideration because they had occurred in these patients, which may have confounded Hct estimation.

6. Conclusions

The present study reveals that HBL in PELD surpasses initial expectations, with the utilization of supplementary decompression techniques and extended surgical durations demonstrating an exacerbating effect on PELD-related HBL. Consequently, our findings underscore the imperative nature of incorporating HBL considerations into the surgical management of elderly and debilitated patients undergoing PELD procedures.

Funding

This work was supported by National Natural Science Foundation of China (No. 82102636), Guangdong Basic and Applied Basic Research Foundation (No. 2020A1515110545 and 2022A1515012557), Guangzhou Municipal Science and Technology Project (No. 2024A04J10010).

Ethics statement

This study was reviewed and approved by the Ethics Committee of Guangdong Provincial People's Hospital, China. (No. GDREC2020191H)

Data availability statement

The data will be made available upon request from the corresponding author.

CRediT authorship contribution statement

Chong Chen: Writing – review & editing, Funding acquisition, Data curation, Conceptualization. **Wenlin Ye:** Writing – review & editing, Software, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Zhengran Yu:** Writing – review & editing, Formal analysis. **Xiaoqing Zheng:** Writing – review & editing, Investigation. **Jingxing Dai:** Writing – review & editing. **Jun Ouyang:** Writing – review & editing. **Dan Xiao:** Writing – review & editing. **Yunbing Chang:** Writing – review & editing, Project administration, Methodology, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] M.E. Brecher, T. Monk, L.T. Goodnough, A standardized method for calculating blood loss, Transfusion 37 (1997) 1070–1074, https://doi.org/10.1046/j.1537-2995.1997.371098016448.x.
[2] K.R. Sehat, R. Evans, J.H. Newman, How much blood is really lost in total knee arthroplasty?. Correct blood loss management should take hidden loss into account, Knee 7 (2000) 151–155, https://doi.org/10.1016/s0968-0160(00)00047-8.
[3] Y. Smorgick, K.C. Baker, C.C. Bachison, H.N. Herkowitz, D.M. Montgomery, J.S. Fischgrund, Hidden blood loss during posterior spine fusion surgery, Spine J. 13 (2013) 877–881, https://doi.org/10.1016/j.spinee.2013.02.008.
[4] L. Wen, D. Jin, W. Xie, Y. Li, W. Chen, J. Ding, J. Xu, D. Ren, Hidden blood loss in posterior lumbar fusion surgery: an analysis of risk factors, Clin Spine Surg 31 (2018) 180–184, https://doi.org/10.1097/bsd.0000000000000626.
[5] R. Zhang, F. Xing, Z. Yang, G. Lin, J. Chu, Analysis of risk factors for perioperative hidden blood loss in patients undergoing transforaminal lumbar interbody fusion, J. Int. Med. Res. 48 (2020), https://doi.org/10.1177/0300060520937848, 300060520937848.
[6] S. Xu, Y. Liang, J. Wang, G. Yu, C. Guo, Z. Zhu, H. Liu, Blood loss of posterior lumbar interbody fusion on lumbar stenosis in patients with rheumatoid arthritis: a case-control study, Spine 44 (2019) E1045, https://doi.org/10.1097/brs.0000000000003037, e52.
[7] Y. Ogura, J.R. Dimar Ii, J.L. Gum, C.H. Crawford, M. Djurasovic, S.D. Glassman, L.Y. Carreon, Hidden blood loss following 2- to 3-level posterior lumbar fusion, Spine J. 19 (2019) 2003–2006, https://doi.org/10.1016/j.spinee.2019.07.010.
[8] B.S. Xu, Y. Liu, H.W. Xu, Q. Yang, X.L. Ma, Y.C. Hu, Intervertebral fusion with mobile microendoscopic discectomy for lumbar degenerative disc disease, Orthop. Surg. 8 (2016) 241–245, https://doi.org/10.1111/os.12235.
[9] Y.T. Gu, Z. Cui, H.W. Shao, Y. Ye, A.Q. Gu, Percutaneous transforaminal endoscopic surgery (PTES) for symptomatic lumbar disc herniation: a surgical technique, outcome, and complications in 209 consecutive cases, J. Orthop. Surg. Res. 12 (2017) 25, https://doi.org/10.1186/s13018-017-0524-0.
[10] J.S. Jang, S.H. An, S.H. Lee, Transforaminal percutaneous endoscopic discectomy in the treatment of foraminal and extraforaminal lumbar disc herniations, J. Spinal Disord. Tech. 19 (2006) 338–343, https://doi.org/10.1097/01.bsd.0000204500.14719.2e.
[11] A. Kafadar, S. Kahraman, M. Akbörü, Percutaneous endoscopic transforaminal lumbar discectomy: a critical appraisal, Minim. Invasive Neurosurg. 49 (2006) 74–79, https://doi.org/10.1055/s-2006-932184.
[12] S. Ruetten, M. Komp, H. Merk, G. Godolias, Recurrent lumbar disc herniation after conventional discectomy: a prospective, randomized study comparing full-endoscopic interlaminar and transforaminal versus microsurgical revision, J. Spinal Disord. Tech. 22 (2009) 122–129, https://doi.org/10.1097/BSD.0b013e318175ddb4.
[13] Z. Lv, L. Jin, K. Wang, Z. Chen, F. Li, Y. Zhang, L. Lao, C. Zhou, X. Li, H. Shen, Comparison of effects of PELD and fenestration in the treatment of geriatric lumbar lateral recess stenosis, Clin. Interv. Aging 14 (2019) 2187–2194, https://doi.org/10.2147/cia.S226295.
[14] D. Cao, S. Zhang, F. Yang, K. Shen, Z. Tan, Hidden blood loss and its influencing factors after percutaneous kyphoplasty surgery: a retrospective study, Medicine (Baltim.) 97 (2018) e0435, https://doi.org/10.1097/md.0000000000010435.

[15] T. Cai, F. Wang, L. Nan, D. Chen, S. Wang, X. Feng, W. Zhang, L. Zhang, Perioperative hidden blood loss in elderly osteoporotic vertebral compression fracture patients with percutaneous vertebroplasty and influencing factors, Geriatr. Orthop. Surg. Rehabil. 12 (2021) 2151459321996178, https://doi.org/10.1177/2151459321996178.
[16] S. Guo, Z. Yu, C. Wang, M. Zhong, R. Wang, Y. Hu, C. Wang, S. Li, Risk factors of hidden blood loss in unilateral biportal endoscopic surgery for patients with lumbar spinal stenosis, Orthop. Surg. 16 (2024) 842–850, https://doi.org/10.1111/os.14009.
[17] Y. Yang, L. Zhang, B. Liu, M. Pang, P. Xie, Z. Chen, W. Wu, F. Feng, L. Rong, Hidden and overall haemorrhage following minimally invasive and open transforaminal lumbar interbody fusion, J. Orthop. Traumatol. 18 (2017) 395–400, https://doi.org/10.1007/s10195-017-0464-9.
[18] Y. Zhou, X. Fu, M. Yang, S. Ke, B. Wang, Z. Li, Hidden blood loss and its possible risk factors in minimally invasive transforaminal lumbar interbody fusion, J. Orthop. Surg. Res. 15 (2020) 445, https://doi.org/10.1186/s13018-020-01971-5.
[19] G. Askgaard, A.I. Christensen, B. Nordestgaard, M. Grønbæk, J.S. Tolstrup, Alcohol and risk of non-traumatic bleeding events requiring hospital care in the general population: a prospective cohort study, Alcohol 87 (2020) 73–78, https://doi.org/10.1016/j.alcohol.2020.04.009.
[20] C. Li, Y. Xie, Z. Li, M. Yang, X. Sun, J. Fan, H.Y. Zhu, C. Wang, M. Li, Intraoperative blood loss in female patients with adolescent idiopathic scoliosis during different phases of the menstrual cycle, PLoS One 9 (2014) e112499, https://doi.org/10.1371/journal.pone.0112499.
[21] P. Puac-Polanco, À. Rovira, L.M. Shah, R.H. Wiggins, Rodriguez F. Rivas, C. Torres, Imaging of drug-related vasculopathy, Neuroimaging Clin N Am. 34 (2024) 113–128, https://doi.org/10.1016/j.nic.2023.07.003.
[22] D. Scheinichen, H.G. Heuft, C. Renken, B. Jüttner, K. Jaeger, T. Schürholz, R. Blasczyk, S. Piepenbrock, H.A. Elsner, Impact of tobacco smoking on platelet function in apheresis products in vitro, Vox Sang. 86 (2004) 252–256, https://doi.org/10.1111/j.0042-9007.2004.00507.x.
[23] W. Kong, T. Chen, S. Ye, F. Wu, Y. Song, Treatment of L5 - S1 intervertebral disc herniation with posterior percutaneous full-endoscopic discectomy by grafting tubes at various positions via an interlaminar approach, BMC Surg. 19 (2019) 124, https://doi.org/10.1186/s12893-019-0589-2.
[24] K. Sairyo, T. Chikawa, A. Nagamachi, State-of-the-art transforaminal percutaneous endoscopic lumbar surgery under local anesthesia: discectomy, foraminoplasty, and ventral facetectomy, J. Orthop. Sci. 23 (2018) 229–236, https://doi.org/10.1016/j.jos.2017.10.015.
[25] C. Beghé, A. Wilson, W.B. Ershler, Prevalence and outcomes of anemia in geriatrics: a systematic review of the literature, Am. J. Med. 116 (Suppl 7A) (2004) 3s–10s, https://doi.org/10.1016/j.amjmed.2003.12.009.
[26] S.B. Nadler, J.H. Hidalgo, T. Bloch, Prediction of blood volume in normal human adults, Surgery 51 (1962) 224–232.
[27] J.B. Gross, Estimating allowable blood loss: corrected for dilution, Anesthesiology 58 (1983) 277–280, https://doi.org/10.1097/00000542-198303000-00016.
[28] H. Yu, M. Liu, X. Zhang, T. Ma, J. Yang, Y. Wu, J. Wang, M. Li, J. Wang, M. Zeng, L. Zhang, H. Jin, X. Liu, S. Li, Y. Peng, The effect of tranexamic acid on intraoperative blood loss in patients undergoing brain meningioma resections: study protocol for a randomized controlled trial, PLoS One 18 (2023) e0290725, https://doi.org/10.1371/journal.pone.0290725.
[29] A.T. Yeung, P.M. Tsou, Posterolateral endoscopic excision for lumbar disc herniation: surgical technique, outcome, and complications in 307 consecutive cases, Spine 27 (2002) 722–731, https://doi.org/10.1097/00007632-200204010-00009.
[30] M. Pan, Q. Li, S. Li, H. Mao, B. Meng, F. Zhou, H. Yang, Percutaneous endoscopic lumbar discectomy: indications and complications, Pain Physician 23 (2020) 49–56.
[31] H. Zhang, Z.X. Chen, Z.M. Sun, C. Jiang, W.F. Ni, Y. Lin, Y.S. Wu, Comparison of the total and hidden blood loss in patients undergoing open and minimally invasive transforaminal lumbar interbody fusion, World Neurosurg 107 (2017) 739–743, https://doi.org/10.1016/j.wneu.2017.08.113.
[32] H. Wang, K. Wang, B. Lv, W. Li, T. Fan, J. Zhao, M. Kang, R. Dong, Y. Qu, Analysis of risk factors for perioperative hidden blood loss in unilateral biportal endoscopic spine surgery: a retrospective multicenter study, J. Orthop. Surg. Res. 16 (2021) 559, https://doi.org/10.1186/s13018-021-02698-7.
[33] D.D. Sun, D. Lv, W.Z. Wu, H.F. Ren, B.H. Bao, Q. Liu, M.L. Sun, Estimation and influence of blood loss under endoscope for percutaneous endoscopic lumbar discectomy (PELD): a clinical observational study combined with in vitro experiment, J. Orthop. Surg. Res. 15 (2020) 281, https://doi.org/10.1186/s13018-020-01797-1.
[34] J. Chen, X. Jing, C. Li, Y. Jiang, S. Cheng, J. Ma, Percutaneous endoscopic lumbar discectomy for L5S1 lumbar disc herniation using a transforaminal approach versus an interlaminar approach: a systematic review and meta-analysis, World Neurosurg 116 (2018) 412–420, https://doi.org/10.1016/j.wneu.2018.05.075, e2.
[35] P.M. Faris, M.A. Ritter, E.M. Keating, C.R. Valeri, Unwashed filtered shed blood collected after knee and hip arthroplasties. A source of autologous red blood cells, J Bone Joint Surg Am. 73 (1991) 1169–1178.
[36] E. Pattison, K. Protheroe, R.M. Pringle, A.C. Kennedy, W.C. Dick, Reduction in haemoglobin after knee joint surgery, Ann. Rheum. Dis. 32 (1973) 582–584, https://doi.org/10.1136/ard.32.6.582.