Hidden Blood Loss in Percutaneous Endoscopic Lumbar Discectomy (PELD): A Prospective Study

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Abstract

Background: Percutaneous endoscopic lumbar discectomy (PELD) is a minimally invasive technique for treatment of lumbar disc herniation (LDH) that requires only an eight-mm skin incision and promotes faster recovery. It is widely believed that the procedure 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.

Methods: As a prospective observational study, 156 patients, mean age 41.6 years (ranged from 17 to 71), undergoing PELD were finally enrolled between May 2019 and November 2020. The analyzed factors included gender, age, body mass index (BMI), symptom duration, operation approach/technique, operation duration, the presence of associated chronic diseases (e.g., hypertension, rheumatoid arthritis, and diabetes mellitus), and improvements in Visual Analog Scale (VAS), Japanese Orthopedic Association (JOA), and Oswestry Disability Index (ODI) scores. Gross's formula was applied to calculate blood loss from recorded values for patient height, weight, and hematocrit levels before and after surgery. Multivariate linear regression analysis and t test were performed to identify factors that contributed significantly to HBL.

Results: The mean HBL during PELD was 201 ± 126 mL, and the Hb reduction observed post-operatively was 7.4 ± 4.5 g/L. A lateral surgical approach was associated with greater HBL compared with an interlaminar approach. However, no significant differences in VAS, JOA, and ODI score improvements were noted between the two surgical approaches. Increased surgical times and foraminal decompression were identified by multivariate linear regression analysis as linked to increased HBL. As expected, the occurrence of post-operative anemia was significantly associated with HBL. Age, gender, BMI, symptom duration, and associated chronic diseases showed no association with increased HBL during PELD.

Conclusions: HBL is increased in PELD patients with long surgical times and lumbar foraminal decompression.

Introduction

As a minimally invasive surgical procedure, percutaneous endoscopic lumbar discectomy (PELD) offers a potentially improved treatment approach for lumber disc herniation (LDH) and some types of lumbar spinal stenosis (LSS) [1]. With several studies reporting encouraging results, the procedure has several advantages compared to other surgical methods, including a reduced risk of damage to the posterior and paraspinal structures, which further reduces the induced trauma compared with traditional open surgery, thereby also reducing intraoperative blood and promoting more rapid postoperative recovery [2–5]. When performed by an experienced surgeon in clinical practice, significant intraoperative bleeding during PELD is rarely observed, with the estimated blood loss being less than 50 ml [6].

Hidden blood loss (HBL) is an important factor in surgical treatments. Brecher *et al*[7] devised a mathematical model for calculating intraoperative blood loss that takes into account the patient's blood volume (PBV), both the amount and type of red blood cells transfused, the patient's hematocrit (Hct) levels preoperatively and at discharge, the volume of salvaged blood transfused during the procedure, and the amount of hemodilution carried out during surgery. The amount of blood loss calculated by this model is on average 2-fold greater than that estimated by the traditional intraoperative approach for all surgeries. To date, the amount of HBL in PELD and the underlying causes have not been reported. A clear understanding of HBL during PELD and its causes would be valuable for improving this technique and its clinical outcomes.

Therefore, we hypothesized that there may be unappreciated HBL during spinal surgery and performed the present prospective observational study among patients who underwent PELD at our institution and to investigate this possibility and the likely causes. From the patients' clinical data, we calculated the HBL and analyzed several possible risk factors associated with increased bleeding in PELD.

Patients And Methods

Patients

The protocol for this study was approved by the Ethics Committee of Guangdong Provincial People's Hospital. We retrieved the electronic medical records of 323 patients underwent surgical treatment by PELD between May 2019 and November 2020. Patients were excluded according to the following criteria: 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 (≥ 20 cigarettes/day), alcohol (liquor ≥ 90 ml/day or 150 ml/week), or recreational drugs; and 5) current menstruation. The study followed a sample-of-convenience design that included all identified patients who met the inclusion/exclusion criteria.

For each patient, we recorded gender, age, weight, height, body mass index (BMI), hematocrit (Hct) levels before and after surgery, hemoglobin (Hb) levels before and after surgery, coagulation function indexes, the levels at which LHD and LSS were applied, the surgical approach, and comorbidities (e.g., hypertension, rheumatoid arthritis, and diabetes mellitus). The pre-operative durations of symptoms and characteristics were also recorded. All patients received treatment with regular non-surgical techniques or medications (e.g., functional exercise, non-steroidal anti-inflammatory drugs [NSAIDs], and vitamins B_1 and B_{12}) in local or community hospitals prior to surgical therapy, with symptoms continuing to affect their daily life. Two rheumatoid arthritis patients in our cohort accepted PELD and stopped steroid use before surgery. Back and leg pain as well as improvements in daily function were assessed by comparing visual analog scale (VAS), Japanese Orthopedic Association (JOA), and Oswestry Disability Index (ODI) scores on postoperative day 1 versus to preoperative values. No antibiotics were administered during the peri-operative period.

Surgical procedures

All PELD surgeries were performed by senior surgeons. The method used for anesthesia was decided with input from the patients and/or their relatives. The surgery was performed with the patient lying in prone position on a carbon-fiber operating bed, so that X-ray images could be taking during the surgery. A transforaminal approach was used for cases of L4/5 disease and an interlaminar approach was applied for treatment of L5/S1 lesions. 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 epidural fat, nerve root, disc flavum ligament space, herniated disc tissue, and other spinal canal structures were viewed by endoscopy. One typical case has been illustrated in Fig. 1 for simply discectomy and if necessary, percutaneous endoscopic lumbar foraminoplasty (PELF) or percutaneous endoscopic ventral facetectomy (PEVF) was performed with a high-speed drill (Fig. 2) and/or trephine reamer (Fig. 3) for patients with foraminal or lateral recess stenosis undergoing LSS [8,9]. After complete hemostasis was achieved by the bipolar technique, the channel and light source were slowly removed. Finally, the skin incision was sutured with one stitch. During the surgery, the core body temperature was monitored and maintained within the normal range.

Post-operative care

For all patients, complete blood count analysis, including Hct, was performed before the operation and on post-operative day 1. Post-operative day 1 was chosen because by this day, the patients were hemodynamically stable and no further fluid shifts were likely. Anemia was defined based on the measured hemoglobin (Hb) levels according to the World Health Organization thresholds for women (<120 g/L) and men (<130 g/L) [10]. Oral NSAIDs and vitamin B_1/B_{12} were given post-operatively. Patients were discharged 1 or 2 days after surgery.

HBL calculation

The total patient's blood volume (PBV) was calculated as described by Nadler *et al.*[11] using the following formula: PBV = $k1 \times \text{height (m)}^3 + k2 \times \text{weight (kg)} + k3$. For male patients, $k1 = 0.3669$, $k2 = 0.03219$, and $k3 = 0.6041$, and for female patients, $k1 = 0.3561$, $k2 = 0.03308$, and $k3 = 0.1833$. The Gross formula was applied for calculation of the total blood loss (TBL) which equal to HBL in the perioperative period [12]: $TBL = HBL = PBV \times (Hct_{pre} - Hct_{post})/Hct_{ave}$, where Hct_{pre} is the preoperative Hct level, Hct_{post} is the Hct level on post-operative day 1, and Hct_{ave} is the average of the Hct_{pre} and Hct_{post} levels.

Statistical analysis

SPSS version 24.0 (SPSS, Inc., Chicago, IL, USA) was used for all statistical analyses. Differences according to sex or surgical approach were evaluated using independent-samples Student's t tests Differences in anemic status from before to after surgery were identified using the Chi-square test. The Pearson or Spearman method was used to test for correlation with HBL. Multivariable linear regression

analysis was conducted to determine which peri-operative factors were independently associated with HBL from among four quantitative variables (i.e., age, BMI, surgical time, duration of symptoms) and six qualitative variables (i.e., surgical approach, symptomatic side, decompression procedures, hypertension, rheumatoid arthritis, and diabetes mellitus). For qualitative variables, the transforaminal approach, left-side symptoms, decompression, hypertension, rheumatoid arthritis, and diabetes mellitus were designated as “1”. For the interlaminar approach, right-side symptoms, non-decompression, non-hypertension, non-rheumatoid arthritis, or non-diabetes mellitus were designated as “0”. A positive value for the coefficient indicated that the variable positively influenced HBL (the dependent variable), whereas a negative value for the coefficient indicated that the variable negatively influenced HBL. The “Enter” method was applied to incorporate all variables in the model. P values < 0.05 indicated statistical significance.

Results

Demographic Data

From May 2019 to November 2020, 323 patients underwent PELD, and 156 of these patients met the inclusion/exclusion criteria and were included in the present study. The demographic and clinical characteristics of the patients are presented in **Table 1**. The patients ranged in age from 17 to 71 years, and the mean age for all patients in the study was 41.6 years. The pre-operative duration of symptoms in these patients ranged from 6 to 55 months (22.9 ± 12.4 months). No complication has been observed in this cohort.

Clinical Outcomes

No blood products were given to any patient during the study, and no patients required wound drainage. Because essentially no blood loss was noted during the PELD procedure for any patient, visible blood loss was disregarded and HBL was considered a good approximation of total blood loss. The calculated values for percent reduction in Hct level, percent reduction in Hb level, level of Hb loss, duration of symptoms, and HBL are presented in **Table 1**. For all patients, the mean Hb loss was 7.4 ± 4.5 g/L, and the mean HBL was 201 ± 126 mL. The mean HBL did not differ significantly between male and female patients (206±127 mL vs. 216±124 mL, P=0.641). However, the mean HBL for PELD *via* the lateral approach (L4/5) was significantly greater than that for PELD *via* the interlaminar approach (L5/S1) (228±126 mL vs. 179±121 mL, P=0.02). No significant differences (all *P>0.05*) were observed between the two surgical types in terms of the improvements in VAS (5.34 vs 4.68), JOA (77.2% vs 76.2%), or ODI (16.9% vs 18.3%). The 25th-percentile and 75th-percentile cases for HBL were compared, and the details are presented in **Table 2.** Besides HBL, Hb and Hct change, the surgical approach, surgical time and decompression procedure of 25th-percentile cases (*P0.05*) are significantly different from that of 75th-percentile cases.

Contributing factors to HBL

HBL increased relatively proportionately (R^2=0.6545) with increasing surgical time (**Figure 4**), and the comparison of pre-operative to post-operative anemic status showed that HBL was correlated with an increased incidence of post-operative anemia (P=0.000, Chi-square test; **Table 3**).

Correlation analysis revealed significant correlations of increased HBL with surgical time (P=0.001), decompression (P=0.001), and surgical approach (P=0.015) (**Table 4**). Next, multivariable linear regression analysis identified surgical time (P=0.000) and decompression (P=0.001) as positively associated with HBL (**Table 5**).

Discussion

As a minimally invasive technique for treatment of LDH that PELD only requires an eight-mm skin incision and promotes faster recovery for patients. Previously, it has been widely believed that PELD associated with minimal blood loss based on the intra-operative observation. However, significant perioperative HBL is frequently unaccounted for.

In 2000, Sehat *et al* [13] gave further support to the concept of HBL when they reported that HBL during total hip replacement represented 49% of the total blood loss. Recently, HBL has received increased attention among spine surgeons. HBL was shown to constitute approximately 40% of total blood loss during primary and revision posterior spinal fusion surgeries [14]. Wen *et al* [15] reported that significant HBL occurred in patients who underwent posterior lumber fusion surgery for degeneration, especially in cases of multi-level fusion. An additional study concluded that HBL was underestimated and accounted for a large percentage of total blood loss in minimally invasive transforaminal lumbar interbody fusion [16]. HBL was calculated to range from 678 to 1,267 mL in two- or three-level posterior lumbar decompression and fusion [17], suggesting the need to consider HBL in patient management. Furthermore, for patients with rheumatoid arthritis undergoing posterior lumbar interbody fusion, while total blood loss, intraoperative bleeding, and operation time showed no variation, HBL was greater than that for patients without rheumatoid arthritis, particularly for long-segmental surgery [18]. Despite these findings, HBL during PELD is not widely recognized and has not been characterized in the literature. To the best of our knowledge, it is the first prospective observational study of HBL in patients undergoing PELD.

Percutaneous kyphoplasty (PKP) is also a minimally invasive procedure used to treat osteoporotic vertebral compression fractures without drainage, and HBL during PKP is difficult to estimate. Wu *et al* [19] concluded that HBL should not be ignored during the peri-operative period for vertebroplasty, especially in patients who are frail and/or have multiple fractures and have PKP. However, the causes of PELD-associated HBL are still unknown. Several possible sources of HBL in PELD include hemolysis, extravasation of blood into surrounding tissues, residual blood in a dead space, or simple under-estimation of blood loss. In addition, the Hct method has been identified as a reliable way to estimate HBL[20].

The concept of percutaneous posterolateral nucleotomy was introduced in 1973, and PELD was subsequently applied for the treatment of lumbar disc herniation [21]. PELD refers to both percutaneous endoscopic transforaminal discectomy (PETD) and percutaneous endoscopic interlaminar discectomy (PEID). As a minimally invasive spinal procedure, PELD has gained popularity due to its small incision, quick recovery, short hospitalization, and equivalent clinical outcomes compared to open surgery [22]. In the present study, all patients were discharged within 1–2 days post-operation. By comparing with the 25th -percentile and 75th -percentile cases for HBL, we found that surgical approach, surgical time and decompression procedure make a difference and try to make further investigation about risk factors.

The transforaminal approach is the procedure used most commonly to treat most types of herniated nucleus pulposus, except for the intra-canalicular type at L5/S1 with a high iliac crest[9]. Herein, we found that the lateral approach was associated with approximately 50 mL more HBL than the interlaminar approach. The improvements in VAS, JOA, and ODI scores on post-operative day 1 were similar with both surgical approaches. While one study reported no significant differences in estimated blood loss, post-operative periods in bed or hospitalization time between PETD and PEID [23], there remains a lack of sufficient evidence to compare these two approaches. In the present study, a transforaminal approach was elected for treating L4/L5, and an interlaminar approach for treating L5/S1, based on the hypothesis that a transforaminal approach would require cutting through more muscle and induce more trauma. However, our multivariable linear regression analysis showed that the surgical approach in PELD was not associated with the amount of HBL.

Our analysis did reveal 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 extravasation of blood into surrounding tissues and hemolysis [24,25]. In patients who receive treatment for LSS and also undergo foraminoplasty or ventral facetectomy, high-speed drilling and/or trephine reamers are applied, which increases bone-derived bleeding. In the present study, we found that application of decompression procedures was positively correlated with HBL.

The present study has several limitations. The cohort size was small, and control groups were not included. Additionally, the data analysis was not done in a blinded manner. Moreover, post-operative Hct and Hb levels were measured only on post-operative day 1. In future studies, these levels will need to be measured at later time points in order to analyze the return to normal levels. Although core body temperature was monitored and maintained during surgery, a large amount of fluid flushing and other hypothermia factors were difficult to avoid. Fluid shifts had likely already occurred in these patients, which may have confounded Hct estimation.

Conclusions

The results of the current study indicate that HBL is much larger in PELD than previous expectations, which based on the intra-operative observation. The performance of additional decompression

procedures and increased surgical times appear to increase PELD-related HBL. Other factors, such as age and BMI, did not influence HBL in this study. Overall, our findings emphasize the need to consider HBL in PELD, especially when planning surgical treatment for elderly frail patients.

Abbreviations

PELD: percutaneous endoscopic lumbar discectomy

LDH: lumber disc herniation

LSS: lumbar spinal stenosis

HBL: hidden blood loss

VAS: visual analog scale

JOA: Japanese Orthopedic Association

ODI: Oswestry disability index

PELF: percutaneous endoscopic lumbar foraminoplasty

PEVF: percutaneous endoscopic ventral facetectomy

BMI: body mass index

TBL: total blood loss

PBV: patient blood volume

Declarations

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

Ethics approval and consent to participate

This study protocol was approved by the Ethics Committee of Guangdong Provincial People's Hospital (2020-191H) and adhered to the guidelines of the Declaration of Helsinki. All participants provided written informed consent.

Consent for publication

Patients signed informed consent regarding publishing their data and photographs.

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 declare no competing interests.

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Authors' contributions

CC, YBC, and HLG contributed to the conception of the study. CC and DX wrote the manuscript. GYL, RYZ, XQZ, and CXL reviewed the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1 Patient's demographic information

Parameter	Male	Female	L4/5	L5/S1	Total
Number of patients	96	60	101	55	156
Age (years)	38.4±11.1	48.3±15.0	41.2±14.3	40.0±11.9	41.6±13.2
BMI (kg/m^2)	24±3.7	22.5±3.4	23.5±3.9	23.4±3.2	23.4±3.8
Hematocrit level loss (%)	4.6±2.8	5.8±3.3	5.5±3.0	4.3±2.9	5.01±3.02
Hemoglobin level loss (%)	4.2±2.6	5.1±3.2	4.4±2.7	4.3±2.4	4.35±2.51
Hemoglobin loss (g/L)	7.2±4.7	7.7±4.2	7.7±4.7	6.2±4.3	7.4±4.5
Duration of symptom (month)	23.5±13.0	22.9±12.5	24.2±13.2	21.9±12.0	22.9±12.4
Surgical time (min)	98±31	93±35	105±32	83±28	96±32
Hidden blood loss (mL)	206±127	216±124	228±126	179±121	201±126

Table 2 25th-percentile patients of HBL compared with 75th-percentile

	25th-percentile		75th-percentile		*P*
Surgical approach	Transforaminal	Interlaminar	Transforaminal	Interlaminar	
Number of patients	20	19	28	11	***0.05***
Gender	Male	Female	Male	Female	
Number of patients	24	15	25	14	*0.05*
Age (years)	42.9±13.3		41.9±13.8		*0.05*
BMI (kg/m^2)	23±3.1		22.5±3.3		*0.05*
Hematocrit level loss (%)	2±0.7		8±2		***0.05***
Hemoglobin level loss (%)	2.8±1.3		9.3±2.7		***0.05***
Hemoglobin loss (g/L)	3.7±2.1		14.2±3.9		***0.05***
Duration of symptom (month)	24.3±10.2		26.5±15.4		*0.05*
Surgical time (min)	71±27		121±28		***0.05***
Decompression	2		21		***0.05***
Hidden blood loss (mL)	64±29		359±87		***0.05***

Table 3 Result of Chi-square test for anemia

	Anemia	Non-Anemia	*P*
Pre-operation	13	143	
Post-operation	42	114	**0.000***

* *P 0.05*

Table 4 Results of Correlation Analysis for HBL

Parameters	Sig (2-tailed)	P
Gender	-0.029	0.718
Age (years)	-0.035	0.664
BMI (kg/m^2)	-0.080	0.321
Duration of symptom (month)	0.292	0.085
Surgery		
Symptom side	-0.032	0.694
Surgical approach	0.192	**0.016***
Decompression	0.518	**0.000***
Surgical time	0.654	**0.000***
Comorbid conditions		
Hypertension	-0.103	0.202
Rheumatoid arthritis	-0.55	0.492
Diabetes mellitus	-0.025	0.756

* P 0.05

BMI body mass index

Table 5 Results of multiple line regression method for HBL coefficients

Coefficients	Unstandardized β	SE	Standardized β	T	P
Constant	-2.049	23.422	-0.087	0.93	
Surgery					
Surgical approach	3.043	15.172	0.012	0.201	0.841
Decompression	123.956	20.128	0.378	6.158	**0.000***
Surgical time	1.998	0.267	0.484	7.473	**0.000***

Dependent variable: HBL (mL), * P 0.05

Figures

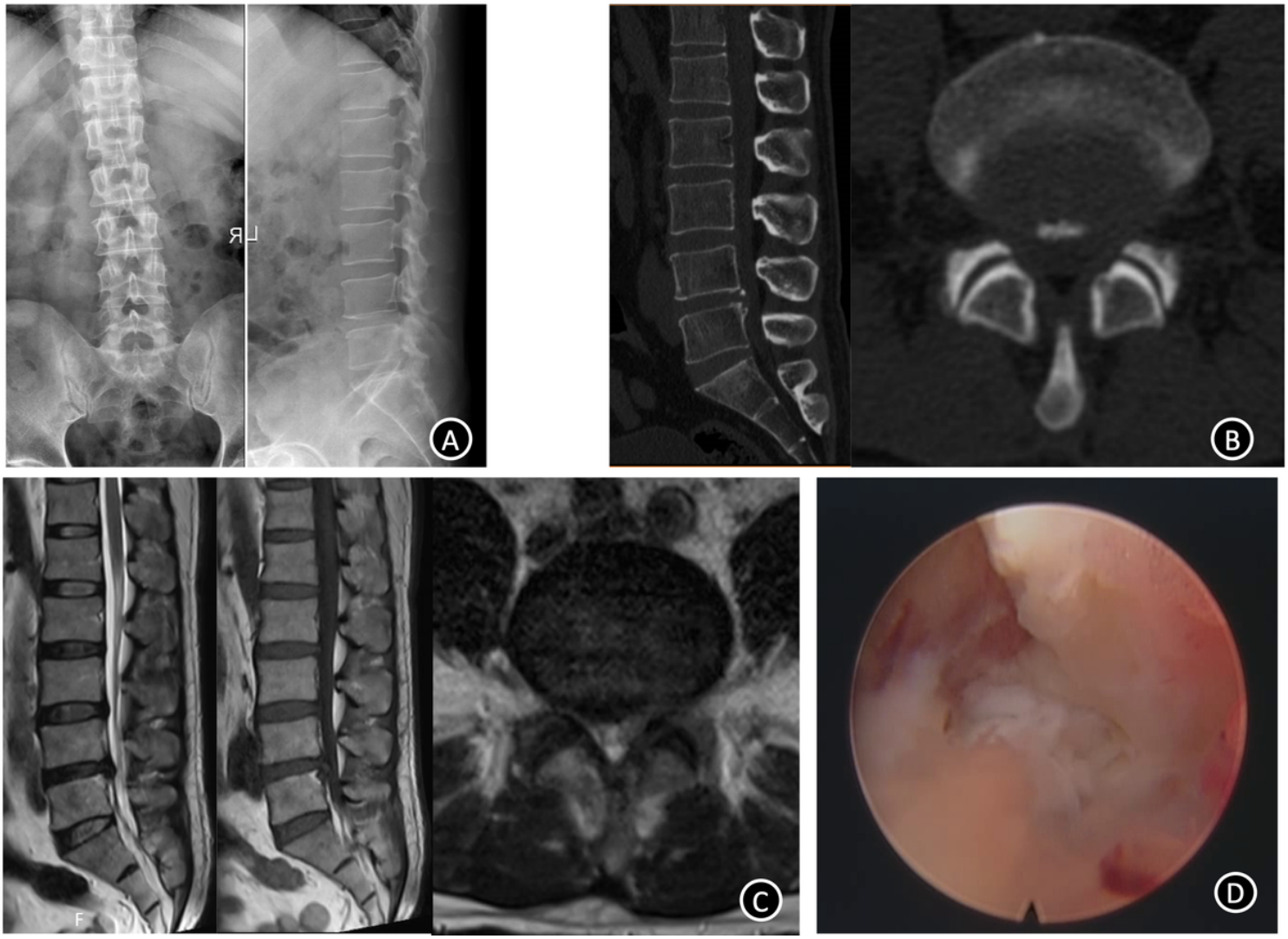

Figure 1

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 (CT) sagittal (left) and axial (right) images indicted that 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.

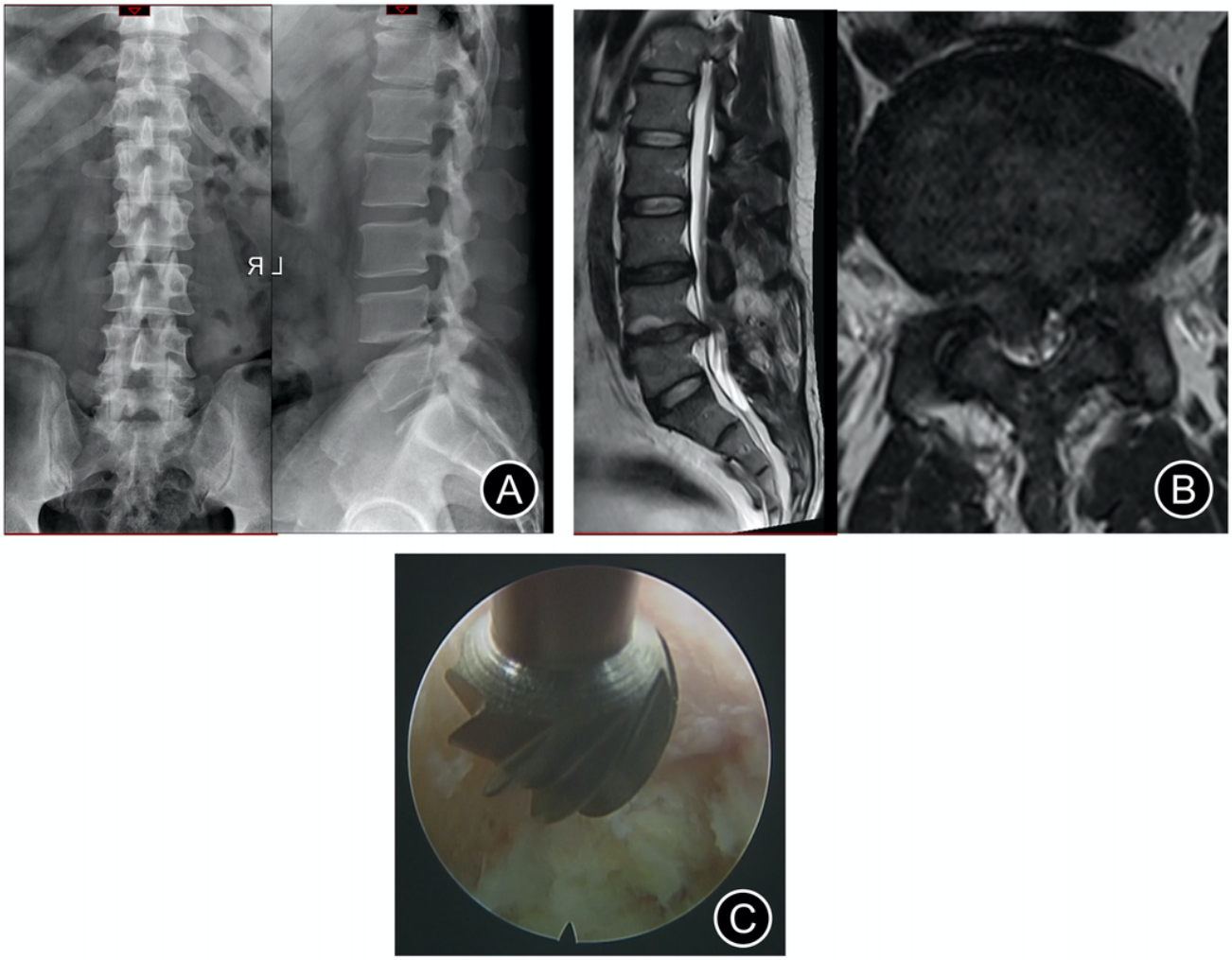

Figure 2

Clinical 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.

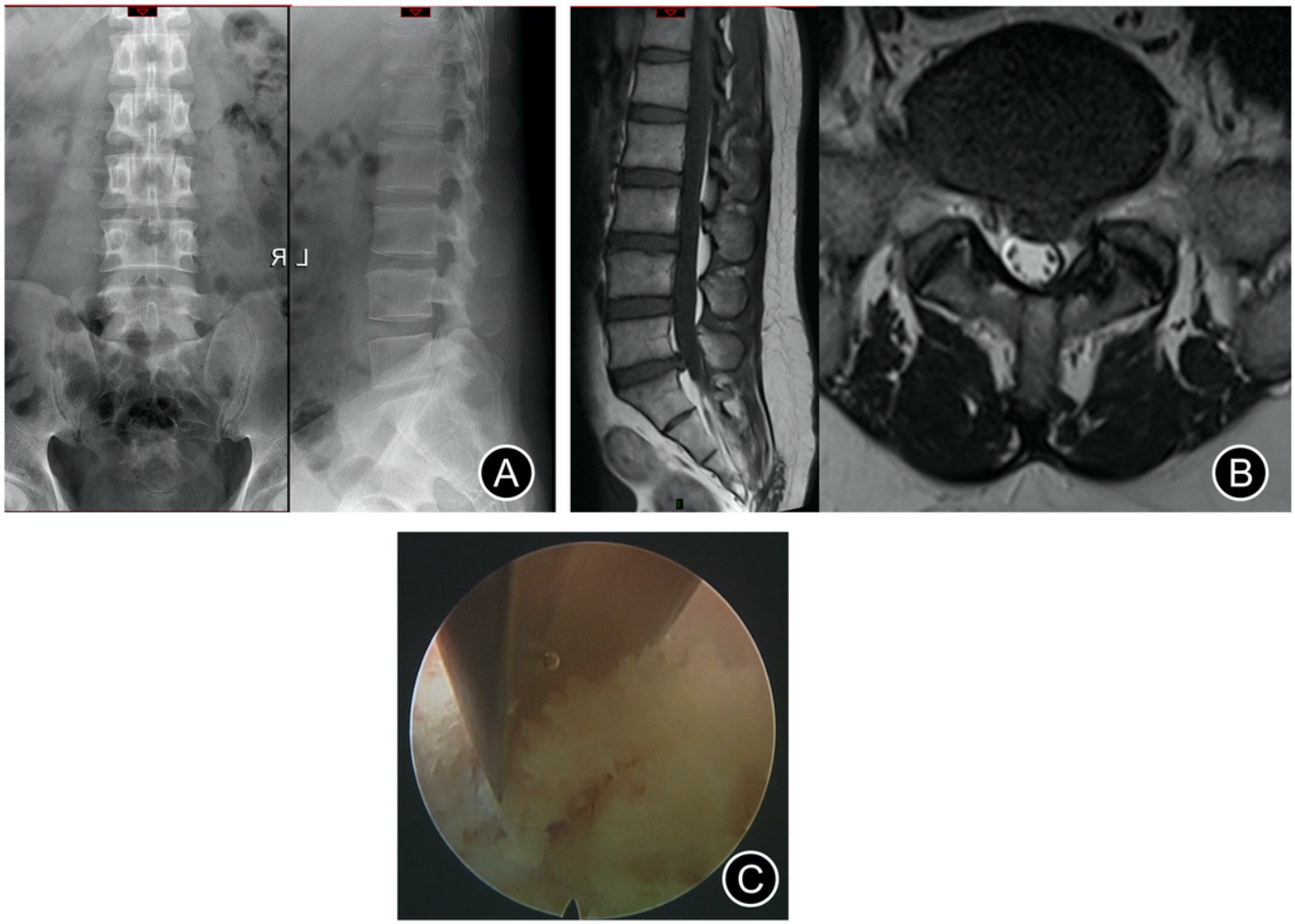

Figure 3

Clinical 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.

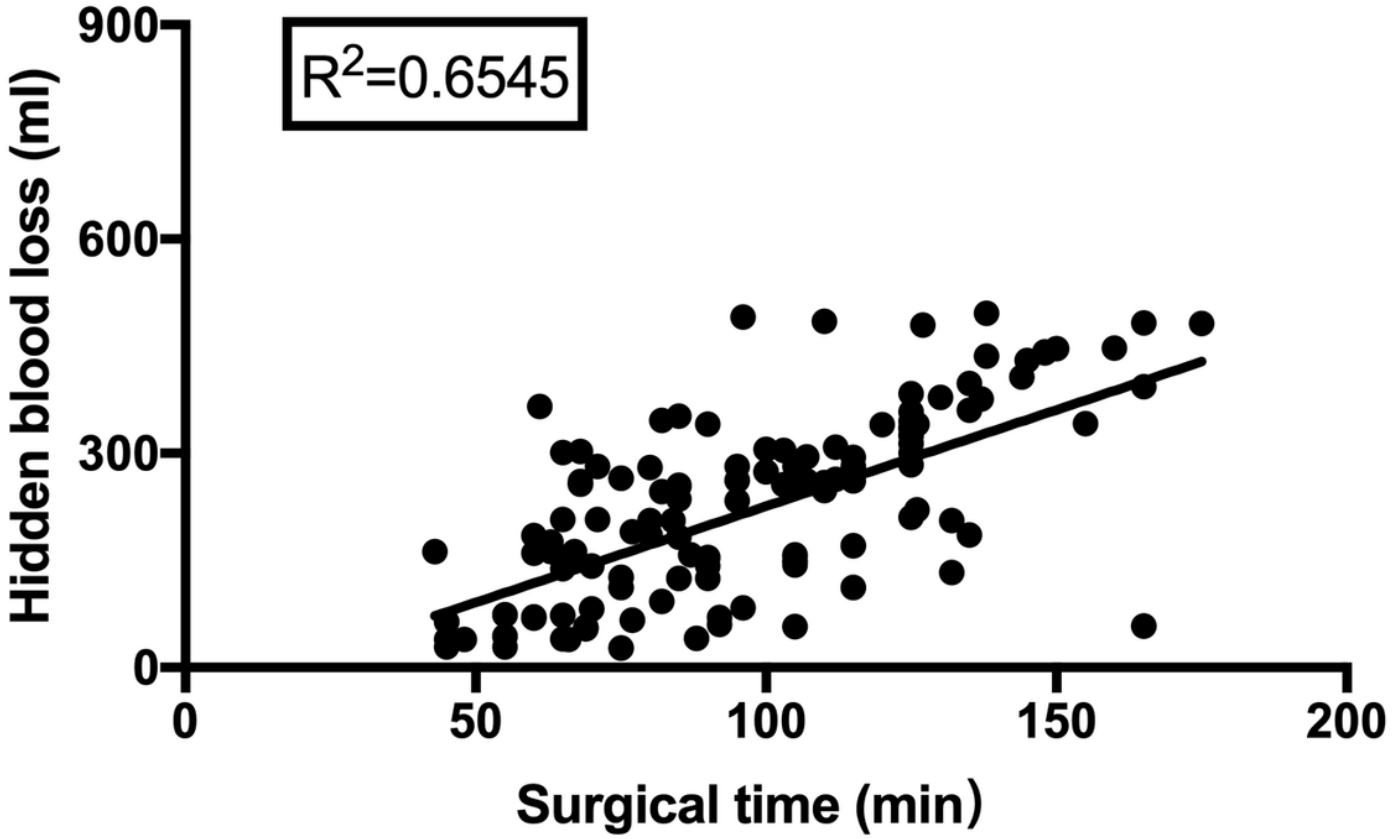

Figure 4

HBL according to surgical time.