Case-Controlled Study

ANNALS OF MEDICINE & SURGERY

OPEN

Hidden blood loss in three different endoscopic spinal procedures for lumbar disc herniation

Haoxiang Zhuang, MM, Jiayi Li, MM, Sijia Guo, MM, Ning An, MM, Zihan Fan, MD, Haining Tan, MD, Jisheng Lin, MD, Nan Su, MD, Yong Yang, MD, Qi Fei, MD*, Hai Meng, MD*

Purpose: This study compared hidden blood loss (HBL) among three different endoscopic spinal procedures and investigated its risk factors.

Patients and methods: This single-centre retrospective analysis collected data from consecutive hospitalized patients with single-segment lumbar disc herniation (LDH) undergoing unilateral biportal endoscopic discectomy (UBE), percutaneous endoscopic transforaminal discectomy (PETD), or percutaneous endoscopic interlaminar discectomy (PEID) from December 2020 to October 2022. HBL was calculated using Nadler's and Gross's formulas. The authors used Pearson's or Spearman's correlation analysis to explore the relationship between patient characteristics and HBL. Multivariate linear regression analysis was used to identify independent risk factors for HBL.

Results: In total, 122 consecutive patients (68 females and 54 males) were enroled in this study. The average HBL was 381.87 ± 218.01 ml in the UBE group, 252.05 ± 118.44 ml in the PETD group and 229.63 ± 143.9 ml in the PEID group ($P < 0.05$). Pearson's or Spearman's correlation analysis showed that operative time, preoperative haemoglobin, preoperative haematocrit, and preoperative Albumin (ALB) were correlated with HBL in the UBE group, while sex, age, operative time, postoperative ALB, and patients' blood volume (PBV) were related to HBL in the PETD group ($P < 0.05$). Operative time and preoperative activated partial thromboplastin time were related to HBL in the PEID group ($P < 0.05$). Multiple linear regression analysis showed a positive correlation between HBL and operative time in all three groups ($P < 0.001$, $P < 0.001$, $P < 0.05$).

Conclusion: HBL was higher in the UBE group than in the PETD and PEID groups, and operative time may be a common risk factor for the three groups.

Keywords: hidden blood loss, lumbar disc herniation, percutaneous endoscopic interlaminar discectomy, percutaneous endoscopic transforaminal discectomy, unilateral biportal endoscopic

Introduction

Lumbar disc herniation (LDH) is the most commonly diagnosed degenerative lumbar disease[1], and it can cause back pain and sciatica, seriously affecting the patient's quality of life. LDH has been reported to affect up to 1% of the population annually[2]. Although some patients' symptoms may be relieved by conservative treatment, discectomy surgery is still required for patients in whom conservative treatment has failed[3,4]. Traditional surgery has some disadvantages, such as heavy muscle damage, long operative time, significant intraoperative bleeding, and a high incidence of postoperative complications. Given the disadvantages of open discectomy for LDH, minimally invasive spinal surgery has been widely used for the treatment of LDH.

Unilateral biportal endoscopic discectomy (UBE) is an emerging minimally invasive spinal procedure. Notably, the technique has two separate channels for the endoscope, which provides a clear and expanded surgical field, improves surgical flexibility, and helps surgeons perform precise and extensive decompression[5]. UBE has demonstrated positive results for the treatment of LDH[6,7]. Percutaneous endoscopic lumbar discectomy (PELD) is the current common surgical technique for the treatment of LDH and was first proposed in the 1980s. There are two main approaches for PELD: percutaneous endoscopic transforaminal discectomy (PETD) and

HIGHLIGHTS

- This study compared the hidden blood loss (HBL) in three different endoscopic spinal procedures.
- This study investigated the risk factors of HBL.
- HBL is higher in unilateral biportal endoscopic surgery than percutaneous endoscopic transforaminal discectomy or percutaneous endoscopic interlaminar discectomy.
- Operative time was a common risk factor for HBL in all three groups.

Department of Orthopedics, Beijing Friendship Hospital, Capital Medical University, Xicheng District, China

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

**Corresponding author. Address: Capital Medical University Affiliated Beijing Friendship Hospital, China. Tel.: +861 364 122 5060; fax: +866 313 8585. E-mail: spinefei@126.com (Qi Fei); Tel.: +861 358 157 6426; fax: +866 313 8585. menghaione@aliyun.com (Hai Meng).*

Annals of Medicine & Surgery (2024) 86:655–659

Received 10 October 2023; Accepted 9 December 2023

Published online 3 January 2024

http://dx.doi.org/10.1097/MS9.0000000000001644

percutaneous endoscopic interlaminar discectomy (PEID)[8]. Both PETD and PEID have been proven to be effective in the treatment of herniated lumbar discs and have become the common surgical method for the treatment of LDH[9].

Hidden blood loss (HBL) due to perioperative haemorrhage spreading to tissue, residual dead space, or haemolysis was first noted by Sehat *et al.*[10] in 2000 and has gained the attention of spinal surgeons. An increasing number of studies have shown that HBL increases total blood loss (TBL) and postoperative complications, such as prolonged hospitalization and recovery and cardiovascular and cerebrovascular diseases[11–13]. Therefore, clinicians should strictly control and reduce HBL.

The present study compared HBL in patients with UBE, PETD, and PEID and investigated the associated risk factors. To the best of our knowledge, studies on this topic have been limited.

Material and methods

Patients

From December 2020 to October 2022, data on consecutive inpatients' data treated with UBE, PEID, or PETD were collected. A total of 122 patients were included in this study. The inclusion criteria were as follows: (1) clinical symptoms were mainly unilateral sciatica; (2) MRI suggested unilateral herniation associated with symptoms; and (3) conservative treatment for more than 3 months was ineffective. The exclusion criteria were as follows: (1) segmental instability; (2) VAS-back score greater than 6; (3) recurrent LDHs in the same segment; (4) combined severe central stenosis; (5) cauda equina syndrome; and (6) spinal tumours, lumbar vertebral fracture, and ankylosing spondylitis; (7) extreme lateral lumbar disc herniation. This work has been reported in line with the STROCSS criteria[14]. All procedures are performed by the same team.

Management of blood loss

Intraoperative bleeding (IBL) was estimated by an anesthesiologist based on the intraoperative suction volume and the amount of bleeding in the swab. In addition, to calculate the amount of bleeding, all patients underwent routine blood tests preoperatively and on the first postoperative day. Only UBE was used for postoperative drainage; no drainage was performed after PETD and PEID. No patient required blood transfusion in the perioperative period (from the first day of admission to the first postoperative day).

Calculation of HBL

Nadler's formula[15] was used to calculate the patient's blood volume (PBV):

$$\mathbf{PBV(l)} = k1 \times \mathbf{height(m)}^3 + k2 \times \mathbf{weight(kg)}^2 + k3$$

in males $k1 = 0.3669$, $k2 = 0.03219$, and $k3 = 0.6041$; and in females $k1 = 0.3561$, $k2 = 0.03308$, and $k3 = 0.1833$.

Gross's formula[16] was used to calculate the total blood loss (TBL):

$$\mathbf{TBL(ml) = PBV(l)} \left(\mathbf{HCT_{pre}–HCT_{post}}\right)/\mathbf{HCT_{ave}}$$

Hct_{pre} is the first day of admission, Hct_{post} is the first postoperative day, and Hct_{ave} is the average of Hct_{pre} and Hct_{post}.

Then, HBL was calculated as follows:

$$\mathbf{Visible\ blood\ loss\ (VBL) = IBL + postoperative\ drainage}$$

$$HBL = TBL - VBL$$

Statistical analysis

The Shapiro–Wilk test was employed to assess the normality of the data. Normally distributed data are presented as mean ± standard deviation, whereas non-normally distributed data are presented as median and interquartile range (IQR). Kruskal–Wallis test and analysis of variance (ANOVA) were used to compare the differences among the three groups. Pearson and Spearman correlation analyses as well as multiple linear regression analysis were employed to establish connections between several independent factors. Data analysis was conducted using RStudio (2022.12.0 + 353, Posit Software, PBC), and statistical significance was set at a threshold of P less than 0.05.

Results

A total of 122 patients (68 females, 54 males) were retrospectively reviewed. There were three groups in the present study: the UBE group (53 patients), PETD group (34 patients), and PEID group (35 patients). Demographic data, including age, sex, BMI, and surgical segments, were not significantly different between the groups ($P = 0.784$, $P = 0.913$, $P = 0.984$, $P = 0.519$, respectively). (Table 1).

Table 2 shows a comparison of the clinical outcomes among the three groups. Preoperative haemoglobin (Hb) and haematocrit (Hct) levels did not differ among the three groups ($P > 0.05$). Compared with UBE, PETD and PEID had significantly lower TBL ($P < 0.05$). Significant differences were observed in VBL ($P <$ 0.05) between the three groups; VBL was significantly higher in the UBE group. HBL was significantly higher in the UBE group ($P <$ 0.05). The operative time was significantly longer ($P = 0.007$) in the UBE group than in the other two groups. The preoperative PLT, preoperative ALB, preoperative PT, preoperative INR, preoperative Fbg, preoperative APTT,

Table 1

Demographics of the study groups

	UBE ($n = 53$)	PETD ($n = 34$)	PEID ($n = 35$)	P
Age, year	56 (41–64)	54.03 ± 12	51.26 ± 15.73	0.784
Sex (n)				0.913
Female	34	18	16	
Male	19	11	11	
BMI	25.28 (22.57–27.76)	25.08 3.09	24.30 (22.97–27.25)	0.984
Surgical segments				0.519
L2–3	1	2	2	
L3–4	2	0	1	
L4–5	25	17	13	
L5–S1	25	10	11	

PEID, percutaneous endoscopic interlaminar discectomy; PETD, percutaneous endoscopic transforaminal discectomy; UBE, unilateral biportal endoscopic.

Table 2

Comparison of perioperative date of UBE, PETD and PEID

	UBE	PETD	PEID	*P*
Preop Hb (g/l)	138.15 ± 18.01	135 (130–147)	142.22 ± 12.11	0.267
Postop Hb (g/l)	125.38 ± 17.47	131 (123–139)	135.3 ± 13.7	0.026
Preop Hct (%)	41.97 ± 5.16	41.45 ± 3.61	42.71 ± 3.27	0.557
Postop Hct (%)	37.53 ± 4.76	39.01 ± 3.48	40.46 ± 3.52	0.012
Preop PLT	242.32 ± 61.2	227.34 ± 58.37	226.44 ± 52.31	0.390
Preop ALB	39.9 ± 3.22	41.02 ± 2.77	40.01 ± 3.91	0.319
Postop ALB	35.00 (33.70–37.80)	38.20 (36.40–39.80)	37.54 3.17	< 0.001
Preop PT	11.28 ± 0.71	11.29 ± 0.6	11.35 ± 0.62	0.887
Preop INR	1.02 ± 0.06	1.02 ± 0.06	1.04 ± 0.06	0.400
Preop Fbg	2.62 (2.35-2.92)	2.68 ± 0.61	2.63 ± 0.43	0.976
Preop APTT	26.6 (25.3–28.8)	26.73 ± 2.37	28.3 (25.85–30.00)	0.165
Preop D-dimer	0.37 (0.27–0.62)	0.26 (0.20–0.42)	0.43 (0.19–0.80)	0.223
ASA classification (*n*)				0.580
I	4	2	4	
II	44	24	21	
III	5	3	2	
IV	0	0	0	
PBV (ml)	3933 (3685–4308)	4248.51 ± 715.18	4502.88 ± 1084.28	0.336
Total blood loss (ml)	450.78 ± 215.92	259.81 ± 118.88	235.92 ± 143.64	< 0.001
Visible blood loss (ml)	60 (52–78)	5 (5–10)	5 (5–7.5)	< 0.001
Hidden blood loss (ml)	381.87 ± 218.01	252.05 ± 118.44	229.63 ± 143.9	< 0.001
Operation time (min)	110 (85–130)	85 (60–110)	88.41 ± 24.53	0.007

ALB, albumin; APTT, activated partial thromboplastin time; ASA, American Society of Anesthesiologists; Fbg, Fibrinogen; Hb, haemoglobin; Hct, haematocrit; INR, international normalized ratio; PBV, patients' blood volume; PEID, percutaneous endoscopic interlaminar discectomy; PETD, percutaneous endoscopic transforaminal discectomy; PLT, platelet; Postop, postoperative; Preop, preopertiative; PT, prothrombin time; UBE, unilateral biportal endoscopic.

preoperative D-dimer level, American Society of Anesthesiologists (ASA) classification, and PBV did not differ among the three groups (all $P > 0.05$).

Table 3

Results of the pearson or spearman correlation analysis for hidden blood loss

	UBE		PETD		PEID	
Parameters	**Cor**	***P***	**Cor**	***P***	**Cor**	***P***
Sex	0.203	0.145	0.399	**0.032**	– 0.310	0.116
Age	– 0.202	0.148	– 0.373	**0.046**	– 0.147	0.464
Surgical segment	0.179	0.200	0.055	0.779	0.093	0.646
Operation time	0.8269	< **0.001**	0.858	< **0.001**	0.556	**0.002**
BMI	– 0.022	0.877	0.147	0.447	0.204	0.307
Preop Hb	0.364	**0.007**	0.195	0.311	0.0911	0.653
Postop Hb	0.015	0.914	0.060	0.757	– 0.186	0.353
Preop Hct	0.383	**0.005**	0.281	0.139	0.189	0.344
Postop Hct	-0.013	0.929	0.016	0.936	-0.175	0.382
Preop PLT	– 0.115	0.413	0.085	0.659	-0.059	0.770
Preop ALB	0.403	**0.003**	– 0.203	0.290	0.334	0.089
Postop ALB	0.053	0.707	– 0.418	**0.024**	0.146	0.468
Preop PT	0.115	0.412	– 0.038	0.845	– 0.030	0.883
Preop INR	0.100	0.477	– 0.109	0.574	– 0.234	0.241
Preop Fbg	– 0.088	0.531	– 0.006	0.977	– 0.022	0.912
Preop APTT	0.153	0.273	– 0.103	0.597	– 0.526	**0.005**
Preop D-dimer	– 0.074	0.600	– 0.163	0.399	– 0.268	0.177
ASA	– 0.183	0.189	– 0.061	0.755	– 0.109	0.589
PBV (ml)	0.095	0.499	0.484	**0.008**	0.096	0.634

Bold values are in statistically significant.

ALB, albumin; APTT, activated partial thromboplastin time; ASA, American Society of Anesthesiologists; Fbg, Fibrinogen; Hb, haemoglobin; Hct, haematocrit; INR, international normalized ratio; PBV, patients' blood volume; PEID, percutaneous endoscopic interlaminar discectomy; PETD, percutaneous endoscopic transforaminal discectomy;PLT, platelet; Postop, postoperative; Preop, preopertiative; PT, prothrombin time; UBE, unilateral biportal endoscopic.

The Pearson and Spearman correlation analysis results are presented in Table 3. The analyses showed that operative time, preoperative Hb level, preoperative Hct level, and preoperative ALB level were related to HBL in the UBE group ($P < 0.05$). Sex, age, operative time, postoperative ALB, and PBV were associated with HBL in the PETD group ($P < 0.05$). Operative time and preoperative APTT were related to HBL in the PEID group ($P < 0.05$). We then performed multivariate linear regression analysis to identify independent risk factors for HBL (Table 4). In the UBE group, the operative time ($P < 0.001$) and preoperative ALB ($P = 0.037$) were significant independent risk factors. In the PETD group, the operative time ($P < 0.05$) was a significant independent risk factor. In the PEID group, the operative time ($P = 0.011$) and preoperative APTT ($P = 0.009$) were significant independent risk factors.

Discussion

Since 2000, HBL has become a growing concern among spinal surgeons. Previous studies have reported that HBL is associated with UBE or PEID in the treatment of LDH. Wang *et al.*[17] reported that the mean HBL during UBE spine surgery was 469.5 ± 195.3 ml, accounting for 57.6% of TBL. Guo *et al.*[18] reported a mean HBL volume of 361.4 ± 216.8 ml in patients treated with UBE lumbar spine surgery. Hu *et al.*[19] retrospectively analyzed 74 patients diagnosed with LDH and treated with PETD, with an HBL of 341.04 ± 191.15 ml. Jiang *et al.*[20] compared the HBL of PETD and UBE for LDH, which were 30.64 ± 22.29 ml and 195.62 ± 130.44 ml, respectively, and the differences were statistically significant. However, no study has compared HBL in the perioperative period for UBE, PETD, and PEID.

Table 4

Multiple linear regression analysis on influential factors of HBL in each group

	UBE	PETD	PEID
Intercept	0.001	0.781	0.020
Sex	NA	0.788	NA
Age	NA	0.796	NA
Operation time	**< 0.001**	**< 0.001**	**0.011**
Preop HB	0.277	NA	NA
Preop HCT	0.196	NA	NA
Preop ALB	**0.037**	NA	NA
Postop ALB	NA	0.290	NA
Preop APTT	NA	NA	**0.009**
PBV	NA	0.133	NA

Bold values are in statistically significant.

ALB, albumin; APTT, activated partial thromboplastin time; Hb, haemoglobin; HBL, hidden blood loss; Hct, haematocrit; NA, not applicable; PBV, patients' blood volume; PEID, percutaneous endoscopic interlaminar discectomy; PETD, percutaneous endoscopic transforaminal discectomy; Postop, postoperative; Preop, preopertiative; UBE, unilateral biportal endoscopic.Pre-op: preopertiative; Post-op: postoperative.

In the surgical treatment of LDH, stripping of paravertebral muscles and soft tissues and removal of bone tissue may damage the vertebral body or paravertebral vessels, resulting in higher IBL. When intraoperative bleeding is high, the volume of blood spreads into tissue spaces and remains high. During surgery for UBE, stripping of the paravertebral muscles and soft tissues and removal of bone tissue can damage the vertebral body or paravertebral vessels, resulting in higher intraoperative bleeding. When intraoperative bleeding is high, the volume of blood that spreads into the tissue spaces and remains high, causing significant HBL in the perioperative period. If surgeons neglect the large volume of HBL generated, the hospitalization time and medical complications may increase.

The present study revealed that UBE patients had significantly higher HBL in the perioperative period than PETD and PEID patients. This might be because the operative time for UBE is longer than those for PETD and PEID. Multiple linear regression analyses showed that the operative time was an independent risk factor for HBL. In UBE, PEID, and PETD surgeries, continuous saline flushes blood oozing from the soft tissues and bone surfaces to maintain a good surgical view; as the operative time increases, more blood is flushed. Choi *et al.*[21] reported that 30 mmHg maintained a clear surgical view and prevented epidural fat and blood vessel damage. There may also be a reason for the higher HBL in UBE, because the additional channel causes more damage to the soft tissues, resulting in increased perioperative bleeding.

Multiple linear regression analysis showed that the preoperative APTT was associated with HBL in the PEID group. The APTT is a blood coagulation test that measures the time taken for blood to form a clot. Yin *et al.*[22] also reported that preoperative APTT was associated with HBL. A lower APTT indicates better coagulation and less occult blood loss in the perioperative period. Multiple linear regression analysis also showed that preoperative ALB level was associated with HBL. This may be due to the fact that the patient's preoperative nutritional status can have an impact on perioperative blood loss. However, this result may be related to the small sample size of this study, and the exact mechanism and results need to be confirmed in a larger sample size.

Pearson or Spearman correlation analysis showed that sex may be associated with HBL in the PETD group, with female patients having less HBL than male patients, which may be related to the relatively small amount of bone resection and smaller back muscles in women than in men. Guo *et al.*[18] found that the HBL increases with the thickness of the paraspinal muscles at target levels in the UBE. From this, it could be seen that women have relatively weak back muscles and therefore have less HBL than men.

This study found that preoperative Hb and Hct levels may affect HBL. Pearson or Spearman correlation analysis suggested that preoperative Hb and Hct were positively correlated with HBL in the UBE and PEID groups, but not in the PETD group. This may be related to the small sample size of this study or perioperative hemodilution. Madsen *et al.*[23] stated that admission Hb level was a risk factor for the volume of blood loss in patients with hip fracture.

This study did not show that age, surgical segment, BMI, postoperative Hb level, ASA classification and postoperative Hct level were associated with HBL. However, different results for other procedures have been reported. For instance, Cushner *et al.*[24] proposed that in total hip replacement surgery, HBL was higher in patients with low BMI. This may be due to the different surgical approaches or small sample size in this study. Wang *et al.*[17] showed that in UBE surgery, the higher the ASA classification is, the greater HBL in patient. And, some study has shown that HBL is much larger in patients with ASA classification III than in those with ASA I and II[13,25]. This study did not come to the same conclusion, which may be due to the fact that most of the cases we included were ASA I and II and few were ASA III. These results should be confirmed in future studies.

Extensive blood loss may result in complications in the postoperative period[26], Wen *et al.*[27] proposed that HBL is positively associated with postoperative complications. One study proposed that HBL is positively associated with postoperative complications. This study suggests that operative time is a common risk factor for HBL, and that HBL is higher in UBE surgery than in PETD or PEID. This may be considered possible because UBE is an emerging technique with relatively few applications. In the future, we should aim to reduce the operative time and intraoperative blood loss, as this will reduce the incidence of surgical complications.

The current study had several limitations. First, this was a retrospective study with a small sample size. A prospective multicenter study with a larger sample size is needed in the future. Additionally, fluid balance is an important basis for calculating the HBL. However, owing to the lack of specific rehydration parameters, we can only draw a limited number of conclusions. Third, because intraoperative blood loss was estimated by anesthesiologists and not accurately quantified, this may have contributed to a bias in the calculation of HBL. Finally, most of the patients in the study were local, so further studies from different regions and countries are needed to verify our results.

Conclusion

The HBL is higher in UBE surgery than in PETD or PEID. Operative time was a common risk factor for HBL in all three groups.

Ethics approval and consent to participate

All experiments were performed in accordance with the Declaration of Helsinki. This retrospective study was approved by the Ethics Committee of the Beijing Friendship Hospital, Capital Medical University (BHF20220602013). Informed consent was obtained from all the participants.

Consent for publication

Not applicable.

Sources of funding

Not applicable.

Author contribution

H.M. and Q.F. performed surgical interventions and designed the study. H.X.Z., J.Y.L., S.J.G., and N.A. performed literature search and data collection. H.X.Z. was a major contributor in writing the manuscript. H.N.T., J.S.L., Z.H.F., N.S., H.M., and Y.Y. contributed to the surgical technical support. All the authors have read and approved the final manuscript.

Conflicts of interest disclosure

The authors declare that they have no competing interests.

Research registration unique identifying number (UIN)

None.

Guarantor

Qi Fei and Hai Meng.

Availability of data and materials

Data are not yet publicly available because studies related to UBE blood loss have not yet been completed but are available from the corresponding author upon reasonable request.

Provenance and peer review

Not commissioned, externally peer-reviewed.

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