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Hidden blood loss and the risk factors after posterior lumbar fusion surgery

A retrospective study

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Abstract

Hidden blood loss (HBL) plays an important role in perioperative rehabilitation of patients underwent posterior lumbar fusion surgery. This study was to calculate the volume of HBL and evaluate the risk factors among patients after posterior lumbar fusion surgery.

A retrospective analysis was made on the clinical data of 143 patients underwent posterior lumbar fusion surgery from March 2017 to December 2017. Recording preoperative and postoperative hematocrit to calculate HBL according to Gross formula and analyzing its related factors including age, sex, height, weight, body mass index (BMI), surgery levels, surgical time, surgery types, duration of symptoms, disorder type, specific gravity of urine (SGU), plasma albumin (ALB), glomerular filtration rate (GFR), glucose (GLU), drainage volume, hypertension. Risk factors were further analyzed by multivariate linear regression analysis and *t* test.

Eighty-six males and 57 females, mean age 52.7 ± 11.4 years, mean height 162 ± 7.0, mean weight 61.5 ± 9.4, were included in this study. The HBL was 449 ± 191 mL, with a percentage of 44.2% ± 16.6% in the total perioperative blood loss. Multivariate linear regression analysis revealed that patients with higher BMI (*P* = .026), PLIF procedures (*P* = .040), and more surgical time (*P* = .018) had a greater amount of HBL. Whereas age (*P* = 0.713), sex (*P* = .276), surgery levels (*P* = .921), duration of symptoms (*P* = .801), disorder type (*P* = .511), SGU (*P* = .183), ALB (*P* = .478), GFR (*P* = .139), GLU (*P* = .423), hypertension (*P* = .337) were not statistically significant differences with HBL.

HBL is a large proportion of total blood loss in patients after posterior lumbar fusion surgery. BMI >24 kg/m^2, PLIF procedures, and more surgical time are risk factors of HBL. Whereas age, sex, surgery levels, duration of symptoms, disorder type, SGU, ALB, GFR, GLU, hypertension were not associated with HBL.

Abbreviations: ALB = plasma albumin, BMI = body mass index, GFR = glomerular filtration rate, GLU = glucose, GU = specific gravity of urine, Hb = hemoglobin, HBL = hidden blood loss, Hct = hematocrit, LDH = lumbar disc herniation, LS = lumbar spondylolisthesis, LSS = lumbar spinal stenosis, PBV = patient's blood volume, PLIF = posterior lumbar interbody fusion, TBL = total blood loss, TLIF = transforaminal lumbar interbody fusion.

Keywords: hidden blood loss, lumbar posterior fusion, multivariate linear regression analysis, risk factors, total blood loss

1. Introduction

Remarkably intraoperative blood loss is a universal trouble that can been encountered, particularly, in multilevel spine fusion procedures.[1] In daily clinical experience, the blood loss measured after posterior lumbar fusion surgery includes merely the intraoperative blood loss and postoperative drainage volume. Although, an obviously satisfactory blood management on blood loss, patients still had encountered anemia, some other factors for blood loss may be neglected. In 2000,[2] Sehat et al first put forward the concept of HBL, which is mean of extravasation of blood into interstitial tissue and hemolysis. It can explain this phenomenon. HBL plays an important role in perioperative rehabilitation of patients undergoing posterior lumbar fusion

Editor: Xiaoxing Xiong.

Consent for publication: Not applicable.

Competing interests: The authors report no conflicts of interests.

Funding: This study was funded by Scientific research project funds of health and family planning commission of Sichuan province (17PJ209), Office of Science & Technology and intellectual property of Luzhou City, Sichuan province (2015LSKZ146).

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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How to cite this article: Lei F, Li Z, He W, Tian X, Zheng L, Kang J, Feng D. Hidden blood loss and the risk factors after posterior lumbar fusion surgery: A retrospective study. Medicine 2020;99:19(e20103).

Received: 21 April 2019 / Received in final form: 4 March 2020 / Accepted: 2 April 2020

http://dx.doi.org/10.1097/MD.0000000000020103

surgery. And gradually received more attention by surgeons in recent years.[3–8] However, few study focusing on the risk factors of HBL after posterior lumbar fusion surgery. In our study, we retrospectively investigated the amount of HBL during posterior lumbar fusion surgery, and meanwhile analyzed the risk factors of HBL using multivariate linear regression analysis and *t* test.

2. Patients and methods

2.1. Patients

Retrospective analysis the clinical data of those patients who underwent posterior lumbar fusion surgery from March 2017 to December 2017. This study protocol was reviewed and approved by the Ethics Committee of the Affiliated Hospital of Southwest Medical University. The Ethics Committee particularly approved that informed consent was not required because of the characteristic of retrospectively study and data were analyzed anonymously. All surgeries were performed by the same experienced surgeon in our department. Inclusion criteria are lumbar spinal stenosis and lumbar disc herniation with instability indicated for lumbar fusion surgery, lumbar spondylolisthesis, revision posterior spinal fusion surgery. Exclusion criteria are lumbar tumor, tuberculosis, fracture, cerebrospinal fluid leakage during surgeries, coagulation dysfunction, patients with medications of anti-platelet aggregants, anemia before surgeries, and received bank blood.

2.2. Surgical procedures

All operative procedures were performed by a senior surgeon with a 10-year experience. The patients were placed in prone position with the abdomen and administered with general anesthesia. A posterior midline incision was made at the skin, and bilateral incision of lumbodorsal fascia with 2 cm paraspinous process, using the Wiltse paraspinal muscle splitting approach through the longissimus and multifidus. The post column structure including the lamina and the facet joint was exposed. After pedicle screw instrumentation, unilateral or bilateral laminotomy and partial facetectomy were performed according the patient's symptoms (The transforaminal lumbar interbody fusion [TLIF] technique decompression range is only facetectomy). The thecal sac and nerve roots are carefully taken to protect with a retractor. After exposure of the posterior annulus, completely discectomy and cartilaginous endplate were performed using disc shavers, rongeurs, and curved curettes. After adequate decompression with the neural elements had been performed, adequate autologous bone graft originated from the excision lamina or facet was placed in the anterior intervertebral space. Then, an interbody cage filled with autologous bone with appropriate size was then obliquely placed into the intervertebral space. A standard closure with fascia and skin was performed.

2.3. Data collection

Information collected upon perioperative included: age, gender, height, weight, body mass index (BMI), surgery levels, surgery time, duration of symptoms, disorder type, specific gravity of urine (SGU), plasma albumin (ALB), glomerular filtration rate (GFR), glucose (GLU). All patients had a complete blood count including hematocrit (Hct) before operation and on the second or the third day postoperative. By this time, the patients were hemodynamically stable, and thus, fluid shifts would have been largely completed.[9] The drainage tube was removed 48 hours after operation, and the drainage volume was recorded as the postoperative blood loss. Tranexamic acid was not used and low-molecular-weight heparin was routinely injected to prevent deep venous thrombosis during the postoperative period. Visible blood loss intraoperative was recorded with the anesthetist and included the blood in the suction bottles (after deducting the lavage fluid used during the surgery) and in the soaked sponges that were used during the procedure. Postoperative blood loss was calculated through recording the amount of blood in the drainage volume after it was removed on the second day postoperative. The visible blood loss was calculated as the sum of intraoperative blood loss plus postoperative drainage. No patient received bank blood before surgeries; most surgeries were performed without using a reinfusion system. Allogenic banked blood was transfused intra- and post-operative as indicated. Thirteen patients (9%) required transfusion.

2.4. Calculation of HBL

We calculated the hidden blood loss (HBL) according to a previous study method[10] by deducting the measured blood loss from the calculated total blood loss. The formula used was: HBL = total blood loss − measured blood loss.

To calculate the total blood loss, we first had to estimate patient's blood volume (PBV) in milliliters. The weight and height of all patients were recorded, then the PBV could be calculated by the method introduced by Nadler et al[11]: PBV (L) = k1 × height $(m)^3$ + k2 × weight (kg) + k3; Where k1 = 0.3669, k2 = 0.03219, and k3 = 0.6041 for males, and k1 = 0.3561, k2 = 0.03308, and k3 = 0.1833 for females.

The total red blood cell volume was calculated by multiplying the PBV by the patient's Hct. Consequently, any change in the red cell volume can be calculated by the change in Hct. The red blood corpuscle loss and Hct fall logarithmically, as was published by Ward et al.[12] Nevertheless, because it demands to use the natural logarithm function, it is not convenient to routine use in practical. Gross[10] proposed a linear formula using the patient's average Hct during the perioperative course. It was found that the Gross' s formula closely followed the Ward' s formula. In our study, the total blood loss was calculated according to the Gross formula: Total blood loss = PBV(Hct_{pre}- Hct_{post})/$Hct_{ave,}$ where Hct_{pre} is the initial preoperative Hct, Hct_{post} is the Hct on postoperative day two or three, and $Hct_{ave,}$ is the average of the Hct_{pre}- Hct_{post}. If the patient received allogenic banked transfusion, the total blood loss calculated by Hct was smaller than what should be in actuality. Therefore, the total blood loss is equal to the loss calculated from the change in Hct plus the volume transfused. The formula then changes to HBL = calculated total blood loss + blood infused-measured blood loss. The calculation methods are illustrated in Figure 1.

2.5. Additional measurements

We used Hb concentration to define anemia, with separate threshold values for women and men, as established by the World Health Organization [<120 g/L for women and <130 g/L for men].[13] The transfusion triggers were a hemoglobin concentration less than 80 g/L and Hct below 25%. If the patients is older than 60 years, a hemoglobin concentration <100 g/L was the transfusion trigger.[14] If the patient undergoes a blood transfusion, 1 U of concentrated red blood cells is equivalent

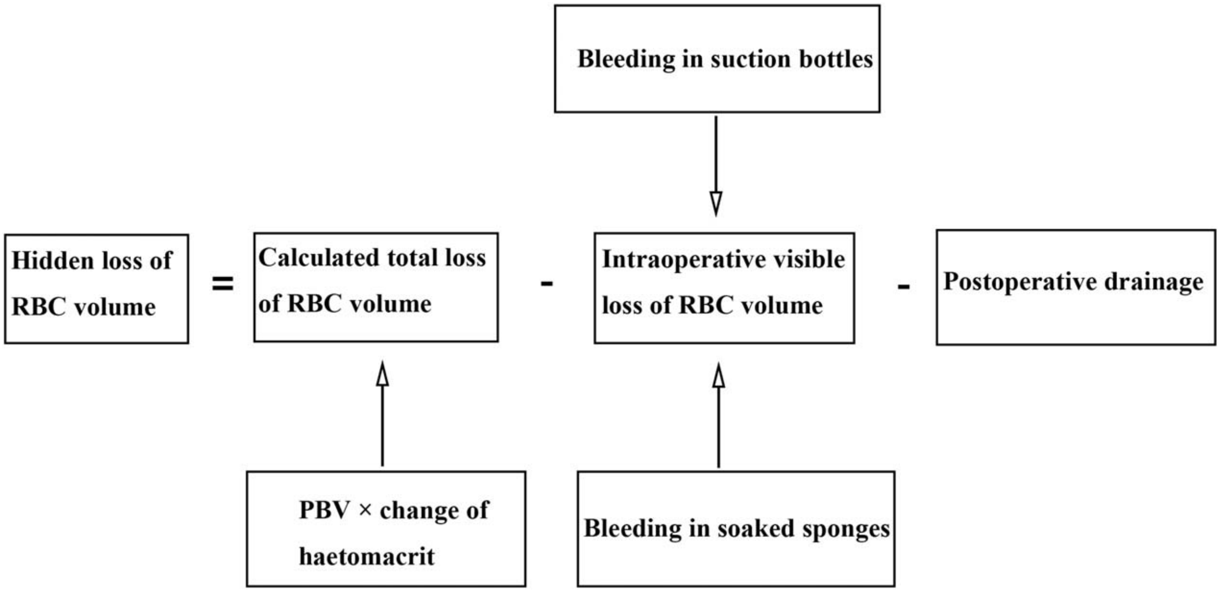

Figure 1. Flowchart for calculating hidden blood loss.

to 200 mL of standard red blood cell volume. BMI was calculated based on the World Health Organization (WHO) criteria.

2.6. Statistical analysis

SPSS 21.0 software was used to perform the statistical analysis (SPSS Inc, Chicago, IL). Data are presented as mean ± SD deviation. Independent samples Student *t* test was used to test for significant differences between males and females. Multivariate linear regression analysis was performed to determine the risk factors of HBL, including 12 quantitative variables (age, height, weight, duration of symptoms, SGU, ALB, GFR, GLU, surgical time, drainage volume, change of Hct between preoperative and postoperative) and 4 qualitative variables (sex, BMI, hypertension, surgery levels, disorder type, surgery type). A positive coefficient indicates a positive influence on the dependent variable (HBL), whereas a negative coefficient indicates a negative influence. All independent variables were incorporated into the model using the method of "Enter." The level of statistical significance was set at $P < .05$.

3. Results

A total of 143 patients, 86 males and 57 females, mean age 52.7 ± 11.4 years, mean height 162 ± 7.0, mean weight 61.5 ± 9.4, were included in this study. 63.6% (91/143) patients' BMI were less than 24, the average surgical time were 159 ± 51, duration of symptoms were 16 ± 7, and 69 patients underwent PLIF surgical procedure, and 74 patients underwent TLIF surgical procedure (Table 1). The data for intraoperative bleeding, Hct level loss, Hb level loss, wound drainage, calculated blood loss, HBL, total blood loss, and the percentage of HBL are shown in Table 2. The mean total blood loss was 1046 ± 342 mL, and the mean HBL was 449 ± 191 mL, with a percentage of 44.2% ± 16.6% in total blood loss.

To determine the relationship between HBL and 16 risk factors, we performed multiple linear regression analysis. As shown in Table 3, the following risk factors were positively related with HBL: BMI ($P = .026$), surgical procedures ($P = .040$), surgical time ($P = .018$). Compared with normal weight, higher BMI patients have the possibility to encounter more HBL in perioperative. The HBL of patients who underwent TLIF was significantly less than for those who accepted PLIF. Meanwhile, we observed that patients with longer surgical time had more

Table 1

Patient's baseline information.

Parameters	Statistic
No. of patients	143
Sex (M/F)	86/57
Age, y	52.7 ± 11.4
Height, cm	162 ± 7.0
Weight, kg	61.5 ± 9.4
BMI	
≤24	91 (63.6%)
>24	52 (36.4%)
Surgery levels	
1	85 (59.4%)
2	51 (35.7%)
3	7 (4.9%)
Surgical time, min	159 ± 51
Surgery type (PLIF/TLIF)	69/74
Duration of symptoms, min	16 ± 7
Disorder type	
LDH	48 (33.6%)
LSS	52 (36.4%)
LS	43 (30.1%)
SGU	1.021 ± 0.009
ALB	41.8 ± 5.0
GFR	95.4 ± 20.2
GLU	4.8 ± 1.0

Data are mean ± SD. ALB = plasma albumin, BMI = body mass index, GFR = glomerular filtration rate, GLU = glucose, GU = specific gravity of urine, LDH = lumbar disc herniation;, LS = lumbar spondylolisthesis, LSS = lumbar spinal stenosis, PLIF = posterior lumbar interbody fusion, TLIF = transforaminal lumbar interbody fusion.

Table 2

Perioperative blood changed in the patients.

Parameters	Mean ± SD
Hemoglobin loss, g/L	26.9 ± 15.0
Hematocrit level loss (%)	0.10 ± 0.03
Intraoperative bleeding, mL	403 ± 220
Wound drainage, mL	190 ± 139
Calculated blood loss, mL	593 ± 286
Total blood loss, mL	1046 ± 342
Hidden blood loss, mL	449 ± 191
Percentage of hidden loss in total (%)	44.2 ± 16.6

Data are mean ± SD.

HBL than the shorter. Nevertheless, it appeared that age ($P=.713$), sex ($P=.276$), surgery levels ($P=.921$), duration of symptoms ($P=.801$), disorder type ($P=0.511$), SGU ($P=0.183$), ALB ($P=0.478$), GFR ($P=0.139$), GLU ($P=.423$), and hypertension ($P=.337$) were not statistically significant differences with HBL.

4. Discussion

The main finding in our study revealed that the volume of HBL was 449 ± 191 mL, with a percentage of 44.2% ± 16.6% in the total blood loss, which was agreed with the results from previous studies, such as, Smorgick et al[3] found that the mean HBL was approximately 40% of total blood loss in posterior spine fusion surgery. Then, using the same calculating method, other author[15,16] reported that the mean HBL after single-level open TLIF was 245.6 ± 97.0 mL, 423 ± 233 mL, being 44.5% ± 12.7%, 66.5% ± 16.1% of the total blood loss, respectively. Our study and previous studies also demonstrated HBL indicating a sizeable amount with total blood loss.

Posterior lumbar fusion surgery is a classical surgical procedure with treatment lumbar disease. The amount of blood loss plays an important role in the rehabilitation of patients after lumbar posterior surgery which is composed of measured blood loss and HBL. The amount of measured blood loss can be easily obtained in clinical practice, which arouses the attention of medical staff and HBL is easily overlooked by us. After Sehat et al. first put forward the concept of HBL, it was gradually aroused attention by surgeon. At the same time, there are also many reports concerned about HBL after lumbar poster fusion surgery.[3,15–17] However, Up to now, no study focused on the risk factors of HBL after posterior lumbar fusion surgery.

What is the reason for HBL? The mainstream explications considered that the mechanisms of HBL is may be ascribed to blood hemolysis, extravasation of the blood into the tissues during the operation, and blood losses during postoperative hospitalization with the continuous blood loss.[18–20] Regarding risk factors of HBL after posterior lumbar fusion surgery, there were not clearly illuminated. In our study, we used multiple linear regression analysis to investigate the correlation factors. The study considered that patients with greater BMI, PLIF procedures, more surgical time would have more HBL.

Our study finds that BMI >24 kg/m^2 increased HBL during perioperative period. Previous studies[21] pay attention to influence of obesity on blood loss post-surgery, without analysis of the cause between BMI and blood loss. We speculate that cardiorespiratory physiology of obese patient is significant altered in anesthetic state. Because of lower central and

Table 3

Multivariate linear regression for factors related to HBL.

	Unstandardized				
	β	SE	Standardized β	T	*P*
Quantitative variables					
Age, y	0.797	2.161	9.093	0.369	.713
Sex (female)	46.823	42.810	23.006	1.094	.276
Duration of symptoms	0.635	2.520	4.121	0.252	.801
SGU	2300.590	1717.415	21.399	1.340	.183
GLU	12.801	15.929	13.317	0.804	.423
GFR	−1.400	0.940	−28.213	−1.490	.139
ALB	−2.276	3.199	−11.539	−0.711	.478
Surgical time	0.795	0.330	40.559	2.409	.018*
Wound drainage	−0.177	0.106	−27.567	−1.676	.096
Height	4.771	3.707	33.689	1.287	.201
Weight	−0.780	3.431	−7.308	−0.227	.821
Qualitative variables					
BMI >24	125.370	55.485	60.521	2.260	.026*
Surgery type (PLIF)	−65.637	31.676	−32.914	−2.072	.040*
Surgery levels (1)					
2	−3.297	33.355	−1.585	−0.099	.921
3	−71.974	75.403	−15.584	−0.955	.342
Disorder type (LDH)					
LSS	−32.415	49.218	−15.648	−0.659	.511
LS	−61.049	42.906	−28.093	−1.423	.157
Hypertension	30.449	31.592	15.003	0.964	.337
Constant	−2730.582	1883.289	448.340	−1.450	.150

Dependent variable: HBL (mL).

* $P<.05$.

ALB = plasma albumin, BMI = body mass index, GFR = glomerular filtration rate, GLU = glucose, GU = specific gravity of urine, LDH = lumbar disc herniation, LS = lumbar spondylolisthesis, LSS = lumbar spinal stenosis, PLIF = posterior lumbar interbody fusion.

peripheral venous pressures, blood loss is less under spinal anesthesia. Increasing ventilation pressures needed to conquer lower pulmonary compliance in obese patient may cause higher venous pressures and greater losses through venous permeation.

Our study illuminates that TLIF has less intraoperative bleeding PLIF. This phenomenon may be contributed to the difference of dissection region. The classic PLIF technique is performed through a wide laminotomy, with resection of the ligamentum flavum and whole removed of the cranial lamina.[22] While TLIF is a modification of the PLIF technique[23] involving hemifacetectomy of the inferior and superior facets with removed of the interarticular so as to access the lateral aspect of disc.

Multivariate linear regression analysis showed that the surgical time was correlated with HBL. In general, the amount of blood oozing in the field increased as the operation went on, it is bound to be closely related to the amount of bleeding, including HBL. This oozing most likely explicates the continual blood loss seen in the closure procedure until the muscle fascia is closed. Therefore, on the premise of safety, shortening the operation time can effectively reduce the amount of intraoperative bleeding. Our result is similar with previous report,[24] which reported 145 patients undergoing spinal posterior fusions mean blood loss was 500 mL at 2 hours,1500 mL at 3 hours, and 2400 mL at 4.5 hours.

The strength of our study was analysed the risk factors for hidden blood loss in patient who underwent posterior lumbar fusion surgery. It was a series of patients' operation by a senior surgeon with a 10-year experience in some department. Our study has several limitations. It is a single-center retrospective study with a small number of cases. Therefore, the generalizability of the results needs to be confirmed with a great deal of patients in daily clinical working. We evaluated postoperative Hct at the second or the third postoperative day, but as fluid shifts would not have been largely completed in a hemodynamically stable, the HBL was falsely low and obviously could influence our conclusions.

In conclusion, HBL is a large proportion of total blood loss in patients after posterior lumbar fusion surgery. BMI $>24\,kg/m^2$, PLIF procedures, and more surgical time are risk factors of HBL. Whereas age, sex, surgery levels, duration of symptoms, disorder type, SGU, ALB, GFR, GLU, hypertension were not associated with HBL. Surgeons should pay more attention to HBL with these patients who are obesity, underwent PLIF procedure and have long operation time after posterior lumbar fusion surgery.

Acknowledgments

The authors thank the relevant staff for guidance and assistance for their support and collaboration in our hospital.

Author contributions

The authors thank the relevant staff for guidance and assistance for their support and collaboration in our hospital.
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Writing – original draft: Fei Lei.
Writing – review & editing: Daxiong Feng.

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