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Hidden blood loss in unilateral open-door cervical laminoplasty for multilevel cervical spondylotic myelopathy

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ABSTRACT

Objectives: This study aims to evaluate the hidden blood loss (HBL) and its possible risk factors after unilateral open-door cervical laminoplasty (UOCL) in patients with multilevel cervical spondylotic myelopathy (MCSM).

Patients and methods: Between January 2018 and March 2023, a total of 105 patients (55 males, 50 females; median age: 76 years; range, 52 to 93 years) who underwent C3-7 UOCL for MCSM were retrospectively analyzed. Data of the patients were recorded, including age, sex, height, weight, plasma albumin, blood glucose, hematocrit, American Society of Anesthesiologists (ASA) score, surgical time, and intraoperative blood loss. The HBL was calculated according to the Sehat formula, and risk factors were identified.

Results: The median surgical time was 180.7 min. The median total blood loss (TBL) and median HBL were 507.4 mL and 201.7 mL, respectively. Correlation analyses revealed that body mass index and surgical time were correlated with HBL ($p<0.05$). However, multiple linear regression analysis showed that HBL was positively correlated with surgical time ($\beta=0.293$, $p<0.05$).

Conclusion: Our study results showed that surgical time is an independent risk factor for HBL. Therefore, HBL should not be overlooked in patients with MCSM undergoing UOCL, particularly in the patients with expected long surgical time.

Keywords: Hidden blood loss, risk factors, unilateral open-door cervical laminoplasty.

Multilevel cervical spondylotic myelopathy (MCSM) is a common degenerative disease in spinal surgery,[1,2] leading to significant functional deterioration and progressive quadriplegia.[3] It results in significant social costs due to medical treatment, subsequent rehabilitation, and derived disabilities.[4,5] Surgery can improve functional status and significantly reduce pain in patients with moderate to severe CSM.[6] For multilevel lesions, posterior surgery is usually adopted,[6-8] with unilateral open-door cervical laminoplasty (UOCL) being the more common procedure.[9,10]

As MCSM occurs mostly in the elderly, perioperative blood management is a very critical aspect. However, in clinical practice, spine surgeons usually focus on intraoperative blood loss (IBL) and postoperative drainage, while often ignoring the presence of hidden blood loss (HBL). In addition, the need for blood transfusion does not exactly coincide with IBL, which explains the presence of HBL.

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The concept of HBL which refers to the hemolysis reaction that occurs after the blood penetrates into the tissue space.[11] It has received more and more attention over recent years. The HBL accounts for a significant portion of total blood loss (TBL) in both open spinal surgery[12,13] and minimally invasive surgery.[14,15] Clarification of HBL allows a more accurate estimation of TBL in the perioperative period and is of great significance to ensure perioperative safety, particularly in elderly patients with preexisting anemia.

To the best of our knowledge, there are few reports in the literature regarding HBL after UOCL. In the present study, we, therefore, aimed to evaluate HBL and to determine the influencing factors by retrospectively analyzing the medical data of MCSM patients who underwent UOCL in our department.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at The Third People's Hospital of Chengdu, Department of Orthopaedics, between January 2018 and March 2023. A total of 105 patients (55 males, 50 females; median age: 76 years; range, 52 to 93 years) who underwent C3-7 UOCL for MCSM were included. All procedures were carried out in accordance with standard guidelines and were performed by a senior surgeon. Exclusion criteria were as follows: *(i)* previous cervical spine surgery; *(ii)* presence of cervical tumors, trauma, and infection; *(iii)* previous coagulation disorders or long-term oral antiplatelet or anticoagulant drugs; *(iv)* administrated with antifibrinolytic agents during surgery (tranexamic acid, or aminocaproic acid); *(v)* incomplete medical information; and *(vi)* intolerance or refusal of surgery.

Data collection

General and clinical data of the patients were collected, the former including age, sex, height, weight, body mass index (BMI), smoking history, and underlying diseases (diabetes mellitus, hypertension, and coronary heart disease). Clinical data included blood glucose, hematocrit (Hct), albumin (ALB), hemoglobin (Hb), American Society of Anesthesiologists (ASA) score, surgical time, intraoperative bleeding, drainage, and blood transfusion. None of the patients received preoperative blood transfusion.

Calculation of blood loss

All procedures were performed by a senior surgeon with 20 years of surgical experience. The surgical incision was approximately 14 cm from the inferior border of the C2 spinous process to the inferior border of the C7 vertebral body. The segments of UOCL were C3-7. The IBL could be obtained on the anesthesiologist's record sheet, which consisted mainly of blood in intraoperative suction bottles, gauze and sponges (excluding intraoperative lavage fluid). All patients had their wounds drained postoperatively. The amount of blood in the drainage bottles on the second or third day after surgery was calculated as the postoperative blood loss (PBL). This definition was based on the fact that at this time point, any fluid transfer was essentially complete.[16] The visible blood loss (VBL) was calculated as the sum of IBL and PBL. The HBL was obtained by subtracting VBL from TBL.[16]

To calculate the TBL, we first calculated the patients' preoperative blood volume (PBV). Then, TBL was calculated by multiplying the change in Hct by PBV according to the Gross formula as follows:[17]

$$PBV\ (L) = k1 \times height\ (m)^3 + k2 \times weight\ (kg) + k3$$

The above coefficients were different for males and females. For males, k1, k2, k3 were 0.3669, 0.03219, and 0.6041, respectively, while for females they were 0.3561, 0.03308, and 0.1833, respectively.

$$TBL\ (mL) = PBV\ (L) \times (Hct_{pre} - Hct_{post}) / Hct_{ave} \times 1000$$

The Hct_{ave} was the average of the initial preoperative Hct (Hct_{pre}) and Hct on the second or the third postoperative day (Hct_{ave}).

If the patient received a blood transfusion (autologous blood or stock blood) during the pre- and postoperative blood test, the transfusion should be included in the HBL. If no transfusion was received, the transfusion was 0 mL. At this point, the HBL was calculated according to the following formula: HBL (mL) = TBL (mL) + transfusion (mL) - VBL (mL).[18]

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 25.0 software (IBM Corp., Armonk, NY, USA). Continuous data were expressed in mean ± standard deviation (SD) or median (min-max), while categorical data were expressed in number and frequency. The Pearson correlation coefficient analysis (for normal distribution data), Spearman correlation coefficient analysis (for non-normal distribution data), multiple linear regression analysis, and analysis of variance (ANOVA) were performed to identify independent risk factors associated with HBL. A p value of <0.05 was considered statistically significant.

RESULTS

Patient characteristics

Of a total of 105 patients included in the study, the median BMI was 20.8 (range, 15.1 to 27.6) kg/m^2. More than 20% of the patients were smokers. Comorbidities included hypertension in 17 patients, diabetes mellitus in 30 patients, and coronary heart disease in 13 patients (Table I).

Clinical data

The median preoperative Hb and median preoperative Hct were 12.5 g/dL and 37%, respectively.

TABLE I
Demographic and clinical characteristics of patients

Variables	n	%	Mean±SD	Median
Age (year)	-	-		76
Sex				
Male	55	52.4		
Female	50	47.6		
Height (m)				1.64
Weight (kg)	56	-		
Body mass index (kg/m^2)				20.8
Smoking	24	22.9		
Comorbidity				
Hypertension	17	16.2		
Diabetes mellitus	30	28.6		
Coronary heart disease	13	12.4		
Preoperative Hb (g/dL)			12.5±1.1	-
Postoperative Hb (g/dL)			10.3±0.9	-
Hb loss (g/dL)				2.3
Preoperative Hct	37	-		
Postoperative Hct			33±30	
Hct loss			5±1	
Preoperative ALB (g/L)			35.5±3.2	
Preoperative blood glucose (mmol/L)				5.49
ASA classification				
I	5	4.8		
II	80	76.2		
III	20	19.0		
Preoperative anemia				
Yes	50	47.6		
No	55	52.4		
Surgical time, min			180.7±35.3	
HBL (mL)			201.7±77.5	
IBL (mL)				279.9
PBL (mL)			147.0±39.8	
Blood transfusion				
Yes	55	48.6		
No	50	51.4		
TBL (mL)				507.4
Total	105	100		

SD: Standard deviation; Hb: Hemoglobin; Hct: Hematocrit; ALB: Albumin; ASA: American Society of Anesthesiologists; HBL: Hidden blood loss; IBL: Intraoperative blood loss; PBL: Postoperative blood loss.

Based on the definition of anemia,[19] 50 patients had preoperative anemia. The median surgical time was 180.7 min. The median HBL loss and average Hct loss was 2.3 g/dL and 5%, respectively. A total of 55 patients with Hb less than 7 g/dL were treated with blood transfusion. The median TBL and median HBL were 507.4 mL and 201.7 mL, respectively (Table I).

Risk factors for HBL following UOCL

Correlation analyses revealed that BMI and surgical time were associated with HBL ($p<0.05$) (Table II). We used multiple linear regression analysis to test the relationship between HBL and influencing factors. As shown in Table III, surgical time was positively correlated with HBL ($\beta=0.293$, $p<0.05$).

TABLE II
Correlation analysis between related factors and HBL

Variables	*p*	Correlation
Age	0.734	–0.034
Sex	0.863	–0.017
Weight	0.122	0.152
Body mass index	0.033	0.209
Smoking	0.85	0.018
Hypertension	0.456	–0.073
Diabetes mellitus	0.226	–0.119
Coronary heart disease	0.459	–0.073
Preoperative Hb	0.684	0.040
Preoperative Hct	0.579	–0.055
Preoperative ALB	0.334	0.095
Preoperative blood glucose	0.890	0.014
ASA classification	0.733	0.034
Preoperative anemia	0.799	0.025
Surgical time	0.001	0.320
Blood transfusion	0.163	–0.137

HBL: Hidden blood loss; Hb: Hemoglobin; Hct: Hematocrit; ALB: Albumin; ASA: American Society of Anesthesiologists.

DISCUSSION

Unilateral open-door cervical laminoplasty is a popular technique for the treatment of MCSM. However, in clinical practice, this procedure still causes significant blood loss,[20,21] leading to complications such as anemia. In our study, Hb decreased significantly after surgery (median: 2.3 g/dL), and most of the patients included in the study were elderly patients (median age: 76 years). Therefore, enhancing perioperative blood management in these patients can help to reduce blood loss-related complications and promote rapid recovery.

In the current study, we found that the need for blood transfusion was not consistent with the VBL. In addition, the TBL was greater than the IBL and PBL, indicating the presence of another part of blood loss, namely HBL, that was not realized.[22] In our study, the mean HBL was as high as 201.7±130.4 mL.

The occurrence of HBL has been shown to be associated with extravasation of blood into the tissues and hemolysis.[23,24] However, the influencing factors associated with the amount of HBL have not been clarified yet. In the present study, we used multiple linear regression analysis to analyze the risk factors associated with HBL. The results suggested that HBL was more in patients who had a longer surgical time.

In general, it is effortless to determine that HBL is directly related to surgical time. The prolonged surgical time means that more and more blood is leaking into the tissue interstices and dead space, leading to an increase in HBL. Therefore, surgeons should carefully study the surgical plan and anticipate the possible risks before surgery to avoid prolonging the surgical time due to various accidents during surgery. Furthermore, the operation should be performed delicately to reduce soft tissue injury and bleeding. In addition, prolonged prone position can affect intra-abdominal pressure and increase epidural venous bleeding.[25] Therefore, the abdomen should be kept suspended during surgery to avoid pressure.

A small-scale retrospective study showed that thickness of posterior cervical soft tissue was a risk factor for HBL during UOCL for MCSM.[26] Indeed, this was not difficult to understand, as the thicker the posterior cervical soft tissue, the greater the induced damage to the soft tissue during surgical exposure. Another retrospective study was conducted to predict IBL and HBL in UOCL for cervical ossification of the posterior longitudinal ligament by exploring the spatial relationship between the K-line and osteophyte. The results showed that the HBL was slightly higher in the K-line (–) group than in the

TABLE III
Multiple linear regression analysis of influencing factors on hidden blood loss following unilateral open-door cervical laminoplasty

Independent variables	B value	SE	β	t	*p*
Constant	–19.263	63.411	-	–0.304	0.762
Body mass index	4.958	2.675	0.173	1.853	0.067
Surgical time	0.618	0.197	0.293	3.143	0.002

SE: Standard error; R^2= 0.132, adjusted R^2=0.114, F=7.724, p=0.001.

K-line (+) group.[27] This result may reflect a trend that the more severe the cervical stenosis, the more HBL. However, the two were not statistically significant, and further prospective studies with large sample sizes are needed to confirm this finding.

Spinal orthopedic surgeons should take a series of measures to improve hemostasis and reduce IBL. On the one hand, it helps to expose the surgical field and reduce the surgical time. On the other hand, it can help reduce the need for perioperative blood transfusion. The ultimate effect is to reduce the production of HBL. In addition to some conventional means, such as absorbable gelatin sponge and other hemostatic materials,[28,29] and some studies have recommended the use of tranexamic acid, which can effectively reduce HBL.[30-32]

Nonetheless, there are some limitations to this study. First, this is a single-center, retrospective study with a relatively small sample size, which may have affected the accuracy of certain parameters. Second, we evaluated HBL based on Hct on the second or third day after surgery, which may have led to an underestimation of HBL. Finally, postoperative rehydration may have diluted the blood and led to bias in HBL. Further multi-center, large-scale studies are warranted to draw more reliable conclusions on this subject.

In conclusion, HBL is easily underestimated in patients with MCSM undergoing UOCL, particularly in the patients with prolonged surgical time. Therefore, spinal orthopedic surgeons should pay attention to the risk factors of HBL and optimize perioperative management measures to reduce the adverse effects of HBL in these patients.

Ethics Committee Approval: The study protocol was approved by the The Third People's Hospital of Chengdu Ethics Committee. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: Waived informed consent given the retrospective observational nature of the study and the anonymity of all data.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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