Clinical Research Report

Journal of INTERNATIONAL MEDICAL RESEARCH

Journal of International Medical Research
2019, Vol. 47(8) 3656–3662

DOI: 10.1177/0300060519856987
journals.sagepub.com/home/imr
SAGE

Hidden blood loss and its possible risk factors in cervical open-door laminoplasty

Chao Jiang[1,2,3], Tian-He Chen[3], Ze-Xin Chen[1,2,3], Ze-Ming Sun[1,2,3], Hui Zhang[4] and Yao-Sen Wu[1,2]

Abstract

Objectives: To evaluate hidden blood loss (HBL) and its possible risk factors among patients following expansive open-door laminoplasty (EOLP) for multilevel, cervical spondylotic myelopathy.

Methods: This was a retrospective analysis of data from patients over 18 years of age who underwent posterior cervical EOLP (from C3-C6) in our department from January 2017 to July 2018. HBL was calculated by deducting the observed perioperative blood loss from the calculated total blood loss (TBL) based on the fall in haematocrit level.

Results: 45 patients (35 men and 10 women) were identified. Mean ± SD HBL was 337.2 ± 187.8 ml, which was 46.8% of the total perioperative blood loss (705.2 ± 269.6 ml). Twenty-three patients developed postoperative anaemia. Posterior cervical soft tissue was positively correlated with both TBL and hidden blood loss (HBL) and hypertension was positively correlated with TBL.

Conclusions: HBL following cervical EOLP was significant and should be recognised as a detrimental factor to patient safety during the perioperative period, especially in patients with thick posterior cervical soft tissue.

Keywords

Hidden blood loss, total blood loss, expansive open-door laminoplasty, risk factors, haematocrit

Date received: 20 January 2019; accepted: 23 May 2019

[1]Department of Orthopaedic surgery, The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University, Wenzhou, China
[2]Zhejiang Provincial Key Laboratory of Orthopaedics Wenzhou, China
[3]The Second School of Medicine, Wenzhou Medical University, Wenzhou, China
[4]Department of Orthopaedic surgery, Jincheng General Hospital, Jincheng, China

Corresponding authors:
Hui Zhang, Department of Orthopaedic surgery, Jincheng General Hospital, Jincheng 048006, China.
Email: zhh142@126.com
Yao-Sen Wu, Department of Orthopaedic surgery, Second Affiliated Hospital of Wenzhou Medical University, 109 Xueyuan Xi road, Wenzhou, 325000, China.
Email: wys9453@126.com

Introduction

Expansive open-door laminoplasty (EOLP), developed in 1977 by Hirabayashi, is one of the principal surgical options for the treatment of multilevel, cervical spondylotic myelopathy.[1] Compared with laminectomy, EOLP is a relatively easier procedure, minimally invasive and associated with a lower long-term complication rate.[2] Studies suggest that the average blood loss is significantly lower during EOLP compared with laminectomy.[3] However, in usual practice, blood loss commonly refers to intraoperative blood loss and postoperative drainage.[4] Blood remaining in the dead space, extravasating into tissues and lost to haemolysis is often ignored. Evaluation of this HBL should permit a more accurate and objective assessment of perioperative haemodynamic stability than is currently available.

The existence of HBL was first proposed by Sehat et al.[4] in 2000, and has gained increasing attention over recent years. For example, one study in patients undergoing anterior, lumbar, interbody fusion surgery found that HBL was 39% of the total blood loss.[5] Another study in patients undergoing minimally invasive, transforaminal, lumbar, interbody fusion surgery, found that HBL was up to 67% of the total blood loss.[6] In a study of 115 patients undergoing percutaneous kyphoplasty surgery, average HBL was 282 mL per patient.[7] Consequently, orthopaedic surgeons should be aware that HBL is a significant portion of total blood loss and should appreciate its influence on patient well-being during the perioperative period.

To the best of our knowledge, HBL during EOLP has not previously been assessed. Therefore, we retrospectively reviewed medical data from patients who had undergone EOLP in our department in an attempt to evaluate HBL during this surgery and identify influential factors.

Methods

This retrospective study included all patients over 18 years of age undergoing posterior cervical EOLP (from C3-C6) in our department from January 2017 to July 2018. Patients with bleeding disorders or history of long-term use of anticoagulant drugs were excluded.

Patient data were collected from the hospital's electronic medical records system. Demographic characteristic (i.e., sex, age, weight, height, body mass index [BMI]), pre- and post-operative (i.e., day 2 or 3) haematocrit (Hct) and haemoglobin (Hb) levels, history of trauma, anteroposterior diameter of the vertebral canal (APD), thickness of the posterior cervical soft tissue (T), operative time, hypertension (i.e., blood pressure $\geq$140/90 mmHg), diabetes mellitus (i.e., fasting blood-glucose $\geq$6.1 mmol/l), intraoperative blood loss volume, postoperative drain blood volume and transfusion blood volume, were extracted from the database. The Hb concentration was used to define anaemia (i.e., $<$120 g/L for women and $<$130 g/L for men).[8]

All patients had undergone general anaesthesia, the surgeries had been performed by the same spinal surgeon and the extent of the incision between C3 and C6 vertebrae was approximately 12 cm. Wounds were drained in all patients and only two patients had received blood bank material during the perioperative period.

Intraoperative blood loss was calculated by weighing the sponges used during each procedure, measuring blood volumes in suction bottles, and subtracting the volume of lavage fluid used during operation. Postoperative blood loss was calculated by measuring the amount of blood in drainage bottles before they were removed on the second or third postoperative day. At this time, the patients would have been hemodynamically stable and any fluid shifts would be largely complete.[9]

The patient blood volume (PBV) was calculated using the formula of Nadler:[9,10]

$$PBV(l) = k_1 \times height(m^3) + k_2 \times weight(kg) + k_3$$

For men, $k_1 = 0.3669$, $k_2 = 0.03219$, and $k_3 = 0.6041$; for women, $k_1 = 0.3561$, $k_2 = 0.03308$, and $k_3 = 0.1833$.

Total perioperative blood loss (TBL) was calculated using Gross' formula.[11] whereby the PBV was multiplied by the change of HCT.[8]

$$\mathrm{TBL}(l) = \frac{\mathrm{PBV}(l) \times (\mathrm{Hct_{pre}}–\mathrm{HCT_{post}})}{\mathrm{HCT_{ave}}}$$

$\mathrm{Hct_{pre}}$ was the initial preoperative Hct; $\mathrm{Hct_{post}}$ was the Hct on the second or third postoperative day; $\mathrm{Hct_{ave}}$ was the average of $\mathrm{Hct_{pre}}$ and $\mathrm{Hct_{post}}$.

HBL was calculated according to the method of Sehat et al.[9] whereby measured blood loss (i.e., sum of intraoperative and postoperative blood loss) was deducted from the calculated TBL.

$$\text{Hidden blood loss} = \text{TBL} - \text{measured blood loss}$$

If a re-infusion or an allogenic transfusion was performed, the TBL was smaller than expected because re-infusion artificially elevated the Hct. Therefore, the TBL was equal to the loss calculated from the Hct change plus the volume transfused. The formula was as follows:

$$\text{Hidden blood loss} = \text{TBL} + \text{blood infused} - \text{measured blood loss}$$

The APD and thickness of the posterior cervical soft tissue (T) were measured at the level of the upper endplate by computed tomography (CT) for each of the vertebra (C3 to C6) (Figure 1). The following formulae were used:

$$APD_{average} = \frac{APD_{C3} + APD_{C4} + APD_{C5} + APD_{C6}}{4}$$

$$T_{average} = \frac{(T_{C3} + T_{C4} + T_{C5} + T_{C6})}{4}$$

T was the mean distance from the midpoint of the lamina to the surface of the skin (i.e., the average length of T on the left side (T_L) and T on the right side (T_R).

The study protocol was approved by the ethics committee at our hospital (Wenzhou, Zhejiang Province, China). Due to the study's retrospective design, there was no requirement for patients' informed consent.

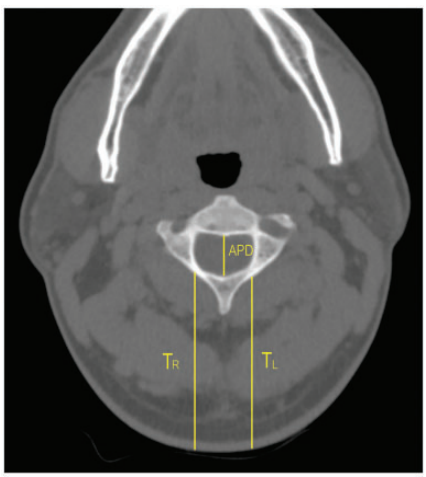

Figure 1. Computed tomography (CT) image of transverse section of cervical spine showing anteroposterior diameter of the vertebral canal (APD) and the thickness of the posterior cervical soft tissue (T). T was the mean distance from the midpoint of the lamina to the surface of the skin (i.e., the average length of T on the left side (T_L) and T on the right side (T_R).

Statistical analysis

Data were analysed using the Statistical Package for Social Sciences (SPSS®) for Windows® release 19.0 (SPSS Inc., Chicago, IL, USA) and a P-value <0.05 was considered to indicate statistical significance. Pre- and postoperative anaemia was compared using the χ^2 test. Student t-tests were used to compare differences between pre- and post-operative Hb levels and Hct values. A multivariate logistic regression analysis was used to examine influential factors on TBL and HBL using five quantitative variables (i.e., age, BMI, APD_{ave}, T_{ave} and operative time) and four qualitative variables (i.e., sex, history of trauma, hypertension, and diabetes mellitus). A positive coefficient indicated a positive influence on the dependent variable whereas a negative coefficient indicated a negative influence.

Results

Over the 18-month period, 45 patients (35 men and 10 women) underwent EOLP in our department. Their demographic data are summarized in Table 1 and clinical results are shown in Table 2. The mean ± standard deviation (SD) age of the patients was 60.4 ± 11.5 years (range 34–80 years) and operation time was 124.6 ± 41.3 min.

Table 1. Demographic characteristics of patients who underwent expansive open-door laminoplasty (EOLP).

	Men $n=35$	Women $n=10$	Total $n=45$
Age, years	60.4 ± 11.5	60 ± 10.4	60.3 ± 11.2
Height, m	1.7 ± 0.0	1.6 ± 0.0	1.7 ± 0.0
Weight, kg	67.5 ± 8.3	57.4 ± 6.3	65.3 ± 9.0
BMI, kg/m^2	23.2 ± 2.4	21.4 ± 2.8	22.8 ± 2.6
PBV, l	4.6 ± 0.4	3.7 ± 0.2	4.4 ± 0.5

Data are presented as mean ± standard deviation (SD).
BMI body mass index; PBV, patient blood volume.[8,9]

Hb loss was 20.0 ± 7.6 g/l, total perioperative blood loss was 705 ± 270 ml and HBL was 337 ± 188 ml (i.e., 46.8% of TBL). Twenty-three patients developed anaemia postoperatively and as expected statistically significant differences were apparent between pre- and post-operative Hb and Hct values (Table 3).

Results from the multiple linear regression analyses showed that out of 9 possible risk factors hypertension was negatively correlated and the thickness of the posterior cervical soft tissue was positively correlated with TBL. (Table 4). As shown in Table 5, out of 9 possible risk factors the thickness of posterior cervical soft tissue was positively correlated with HBL.

Discussion

Although HBL is now recognised as a significant proportion of total blood loss, it remains seriously underestimated by most orthopaedic surgeons.[9] Excessive hidden blood loss not only increases medical complications, but also affects postoperative rehabilitation and lengthens hospitalization time which undoubtedly affects patient

Table 2. Perioperative changes during expansive open-door laminoplasty (EOLP).

	All patients $n=45$
Duration of operation, min	124.6 ± 41.3
Haematocrit loss, %	14.8 ± 4.9
Haemoglobin loss, %	14.3 ± 5.2
Haemoglobin loss, g/l	20.0 ± 7.6
Intra-operative blood loss, ml	190.0 ± 177.2
Wound drainage, ml	206.8 ± 86.1
TBL, ml	705.2 ± 269.6
Hidden blood loss, ml	337.2 ± 187.8
Hidden blood loss as a percentage of TBL, %	46.8 ± 15.3

Data are presented as mean ± SD.
TBL, total blood loss.

Table 3. Changes in haemoglobin, haematocrit and anaemia levels following expansive open-door laminoplasty (EOLP).

	Preoperative $n = 45$	Postoperative $n = 45$	Statistical Significance
Haemoglobin, g/l	139.9 ± 18.7	119.9 ± 17.7	$P < 0.001$
Haematocrit, ratio	0.42 ± 0.48	0.36 ± 0.48	$P < 0.001$
Anaemia	11	34	$P < 0.001$

Data are presented as mean ± SD or *n* (%).

Table 4. Multiple linear regression analysis of influential factors on total blood loss following expansive open-door laminoplasty (EOLP).

	Coefficient		
Variable	*B*	*SE*	Statistical significance
Sex	−6.1	11.7	*ns*
Age, years	6.8	3.9	*ns*
BMI, kg/m^2	3.9	16.6	*ns*
History of trauma	17.4	85.9	*ns*
Hypertension	−229.0	94.7	$P = 0.021$
Diabetes mellitus	−44.1	134.8	*ns*
Operative time (min)	1.7	1.0	*ns*
APD, mm	−24.0	20.8	*ns*
T, mm	19.6	7.6	$P = 0.014$

SE, standard error; BMI body mass index; APD, Anteroposterior diameter vertebral canal; T, Thickness of posterior cervical soft tissue; *ns,* not statistically significant.

Table 5. Multiple linear regression analysis of influential factors on hidden blood loss following expansive open-door laminoplasty (EOLP).

	Coefficient		
Variable	*B*	*SE*	Statistical significance
Sex	9.926	87.809	*ns*
Age, years	2.306	3.061	*ns*
BMI, kg/m^2	−4.045	13.009	*ns*
History of trauma	11.222	67.519	*ns*
Hypertension	−147.734	74.457	*ns*
Diabetes mellitus	2.153	105.966	*ns*
Operation time, min	0.924	0.791	*ns*
APD, mm	−5.028	16.330	*ns*
T, mm	12.465	5.985	$P = 0.045$

SE, standard error; BMI body mass index; APD, Anteroposterior diameter vertebral canal; T, Thickness of posterior cervical soft tissue; *ns,* not statistically significant.

satisfaction.[12] Although previous studies measured blood loss associated with EOLP, they ignored HBL.[13,14]

In this retrospective study of patients who had undergone posterior cervical EOLP, HBL was nearly 50% of the TBL, an amount far higher than expected by our orthopaedic surgeons. Moreover, the mean Hb loss was 20 g/L, and 23 patients with normal preoperative Hb levels developed secondary anaemia. Even if drained blood is re-infused, patients may still exhibit substantial HBL and so a patient may be anaemic even after replacement of most visible blood loss.[9] Indeed, marked HBL. is one of the most important causes of anaemia following orthopaedic surgery.[7]

Hidden blood loss is generally ascribed to extravasation of blood into tissues and hemolysis.[15–17] One study found that approximately 60% of HBL was attributable to tissue extravasation during re-infusion and 40% to haemolysis.[9] However, using labelled red blood cells, another study showed that hidden blood loss was caused primarily by perioperative bleeding into tissue compartments.[15]

Results from our multivariate analysis showed that the thicker the soft cervical

tissue, the greater the likelihood of TBL and HBL. There are two possible explanations for this finding. Firstly, the thicker soft cervical tissue may have been associated with soft tissue injury which would have increased intraoperative bleeding. Secondly, the thicker soft cervical tissue may have been associated with larger penetrable tissue compartments which would have allowed blood to infiltrate tissue spaces. These suggestions are consistent with findings from a previous study of patients undergoing total knee arthroplasty.[18] In that study, a long incision and increased soft tissue dissection created more penetrable tissue compartments which subsequently contained large amounts of residual blood. We also found that hypertension was negatively associated with TBL but not HBL. This finding was not surprising because TBL is the combination of visible blood loss (i.e., from the surgery and the wound drainage) and HBL. Therefore, hypertension may independently affect TBL but further larger scale studies are required to confirm our findings.

The duration of surgery and surgery at multiple levels have been shown to be independently correlated with HBL in patients undergoing anterior, lumbar interbody fusion.[5] In addition, in a previous study we found that HBL was directly related to the severity of vertebral injury in patients with vertebral compression fractures.[7] Nevertheless, in this present study, there was no association between operation time or trauma history with HBL. These findings may have been a consequence of low patient numbers and further studies are required to substantiate our findings.

The study had some limitations. For example, this was a retrospective analysis of data from a relatively small group of patients, most of which were male. Further prospective studies using large sample sizes are required to confirm our findings. In addition, based on previous studies we estimated HBL on day 2 or day3 postoperatively.[9] However, this may have not been the optimum time for measurement. Again, more studies are required to confirm the correct time for assessing hemodynamic stability.

In conclusion, a large amount of HBL is associated with EOLP and is underestimated by most orthopaedic surgeons. Hidden blood loss should be considered in patients undergoing EOLP to ensure perioperative safety, especially in those with thick posterior cervical soft tissue.

Acknowledgements

This work was supported by the National Natural Science Foundation of China (81501907); and the Wenzhou Municipal Science and Technology Bureau (Y20150063). We thank all the colleagues for their invaluable assistance during the execution of this study.

Authors' contributions

Hui Zhang and Yao-Sen Wu were responsible for the design of the study, Chao Jiang and Tian-He Chen were responsible for the analysis of the data and writing of the article. Ze-Xin Chen, Ze-Ming Chen and Hui Zhang were responsible for the acquisition and arrangement of the data.

Declaration of conflicting interest

The authors declare that there are no conflicts of interest.

Funding

This study was funded by the National Natural Science Foundation of China (81501907); and the Wenzhou Municipal Science and Technology Bureau (Y20150063).

ORCID iD

Yao-Sen Wu https://orcid.org/0000-0002-2020-1921

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