

## Research Article

# Patient Characteristics Related to Blood Loss in High Tibial Osteotomy in Novel Multiple Linear Regression Analysis

Jia-Wang Zhu , De-Sheng Chen , Tong-Fu Wang, and Yang Xie

Department of Tianjin Hospital, Tianjin, China

Correspondence should be addressed to De-Sheng Chen; 392849261@qq.com

Received 2 February 2020; Accepted 13 April 2020; Published 2 May 2020

Academic Editor: Giulio Gasparini

Copyright © 2020 Jia-Wang Zhu et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

The purpose of the study was to identify patient characteristics related to blood loss following high tibial osteotomy (HTO). We evaluated 48 patients undergoing HTO from August 2018 to August 2019. The data of 48 patients were collected, including gender, age, height, weight, body mass index (BMI), smoking, alcohol consumption, hypertension, diabetes, history of aspirin, and pre-postoperative hematocrit (Hct). Multiple linear regression analysis was used to analyze the risk factors related to blood loss in HTO. The mean age of patients was  $56.6 \pm 10.2$  years, including 22 males and 26 females. The mean BMI was  $28.5 \pm 4.2$  kg/m<sup>2</sup>, and the mean blood loss volume was  $383.3 \pm 181.3$  mL, 13 patients with smoking (27.1%), 15 patients with alcohol consumption (31.3%), 23 patients with hypertension (47.9%), 10 patients with diabetes mellitus (20.8%), and 12 patients with history of aspirin (25.0%). Multiple linear regression model suggested alcohol consumption and BMI were associated with blood loss in HTO,  $R^2 = 0.451$ ,  $F(9, 38) = 3.462$  ( $P < 0.05$ ). Our study indicates that alcohol consumption and BMI are important risk factors related to blood loss in HTO.

## 1. Introduction

High tibial osteotomy (HTO) is an effective procedure for knee osteoarthritis with varus malalignment in young people [1, 2]. As joint preservation surgery, the procedure moderates the mechanical axis of the lower limb to relieve pain [3–8].

HTO is usually performed with tourniquet intraoperative in order to keep a clear vision [9–12]. However, abnormal fibrinolysis induced by tourniquet release increased perioperative blood loss [13–15]. Severe hemorrhage may lead to hematoma, stiffness, infection, delayed healing, and thrombosis [9, 16–20].

Gunter et al. studied 55 patients with HTO and pointed out that the incidence of hematoma was 4.7%, infection was 4.7%, and thrombosis was 2.3% [20]. Seo et al. studied 167 patients undergoing HTO with the TomoFix plate and reported that the incidence of hematoma was 2.4% and stiffness was 1.2 [18]. Martin et al. studied 323 patients undergoing HTO with Puddu or TomoFix plate and reported that the incidence of hematoma was 3%, delayed healing was 12%, cellulitis was 10%, stiffness was 1%, and thrombosis was 1%

[19]. Therefore, accurate preoperative prediction of blood loss in high tibial osteotomy is a matter of great concern to surgeons.

This study retrospectively analyzed 48 patients undergoing HTO from August 2018 to August 2019. The risk factors were studied to provide a basis for assessing blood loss before surgery.

## 2. Methods

**2.1. Patient Selection.** We retrospectively reviewed patients undergoing HTO from August 2018 to August 2019. The inclusion criteria were (1) symptomatic medial osteoarthritis, (2) the first operation, and (3) clinical data integrity. Exclusion criteria were (1) revision surgery, (2) medical disputes, (3) preoperative hemoglobin (Hb)  $< 90$  g/L, and (4) history of thromboembolism. 48 patients were included finally. All operations were performed by the same surgeons.

**2.2. Data Collection.** The data of 48 patients were collected, including gender, age, height, weight, BMI, smoking, alcohol consumption, hypertension, diabetes, history of aspirin, and

TABLE 1: Patient characteristics.

Gender, male:female	22/26
Mean age, years	56.6 ± 10.2
Knee involving, left/right	28/20
BMI, kg/m <sup>2</sup>	28.5 ± 4.2
Smoking	13 (27.1%)
Alcohol consumption	15 (31.3%)
Hypertension	23 (47.9%)
Diabetes mellitus	10 (20.8%)
History of aspirin	12 (25.0%)
Blood loss volume, mL	383.3 ± 181.3

pre-postoperative Hct. The total blood volume was calculated using height and weight by the formula of Nadler et al. [21]. The blood loss was calculated by the Gross formula [22]. Collinearity statistics was used to assess multicollinearity between independent variables, and multiple linear regression analysis was used to analyze the risk factors related to blood loss in HTO. The SPSS 22.0 software was used for statistical analysis, and  $P < 0.05$  was considered statistically significant.

### 3. Results

The average age of the patients was  $56.6 \pm 10.2$  years, including 22 males and 26 females. The mean BMI was  $28.5 \pm 4.2$  kg/m<sup>2</sup>, and the mean blood loss volume was  $383.3 \pm 181.3$  mL. There were 28 patients with left knee surgery (58.3%), 13 patients with smoking (27.1%), 15 patients with alcohol consumption (31.3%), 23 patients with hypertension (47.9%), 10 patients with diabetes mellitus (20.8%), and 12 patients with history of aspirin (25.0%). The characteristics of the patients are shown in Table 1.

The multiple linear regression analysis showed that there is no autocorrelation detected in residuals (the Durbin-Watson value was 2.348), without the presence of multicollinearity (the tolerance value  $> 0.1$  in all independent variables), the regression of standardized residual of blood loss volume follows a normal distribution closely, and the adjusted  $R^2$  value was 0.451.

The multiple linear regression model was statistically significant  $F(9, 38) = 3.462$  ( $P < 0.05$ ), BMI and alcohol consumption are risk factors related to blood loss in HTO ( $P < 0.05$ ), the  $\beta$  value of BMI was 16.0, and the  $\beta$  value of alcohol consumption was 154.6 (Table 2).

### 4. Discussion

HTO is an effective procedure for knee osteoarthritis with varus deformity [23–25]. Akizuki et al. studied 94 cases undergoing lateral closed high tibial osteotomy (CW-HTO) and pointed out that the HSS score increased significantly from  $60.7 \pm 11.2$  preoperative to  $90 \pm 6.9$  postoperative [6]. Niemeyer et al. reviewed 69 patients undergoing medial open wedge tibial osteotomy (OW-HTO) and pointed out that the IKDC score increased significantly from  $47.25 \pm 18.71$  pre-

TABLE 2: Stepwise multiple linear regression models.

	$\beta$	$P$ value
Constant	81.527	
BMI, kg/m <sup>2</sup>	15.996	0.013
Alcohol consumption	154.625	0.010

operative to  $72.72 \pm 17.15$  postoperative [26]. In recent years, OW-HTO has become more popular than CW-HTO with higher correction accuracy and less soft tissue intervention [5, 27–31].

Application of tourniquet, osteotomy at the metaphyseal level, and soft tissue release intraoperative may cause intra- and postoperative bleeding. Kim et al. studied 150 patients undergoing OW-HTO and pointed out that the blood loss volume was  $502.4 \pm 294.9$  mL in the group with tranexamic acid and  $882.7 \pm 482.0$  mL in the group without tranexamic acid [32]. Jeya et al. studied 156 patients undergoing OW-HTO and pointed out that the blood loss volume was  $372 \pm 36$  mL in the group with tranexamic acid and  $635 \pm 53$  mL in the group without tranexamic acid [33]. Our study showed that the blood loss volume was  $383.3 \pm 181.3$  mL without the application of tranexamic acid in all patients.

Severe hemorrhage may lead to hematoma, infection, delayed healing, and transfusion [9, 18, 19, 32–35]. Floerkemeier et al. studied 533 patients undergoing OW-HTO and pointed out that the incidence of hematoma was 2.1%, infection was 2.1%, infected hematoma was 0.6%, and impaired wound healing was 0.4% [34]. Seo et al. studied 167 patients undergoing OW-HTO and pointed out that the incidence of hematoma was 2.4%, deep infection was 0.6%, and nonunion was 0.6% [18]. Theoretically, accurate preoperative prediction and reducing blood loss in HTO can result in less hematoma and better wound healing.

To our knowledge, this is the first study investigating the patient characteristics related to blood loss in HTO. In our multiple linear analysis, we found that BMI and alcohol consumption are risk factors related to blood loss in HTO.

BMI was associated with blood loss which has been demonstrated in other orthopedic surgeries [36–39].

Jibodh et al. pointed out that operative time is longer and blood loss is higher in patients with  $\text{BMI} \geq 40$  kg/m<sup>2</sup> in hip arthroplasty [36]. Frisch et al. studied 2399 patients undergoing total hip arthroplasty (THA) or total knee arthroplasty (TKA) and pointed out that the estimated blood loss of the normal group was  $268.2 \pm 313.9$  mL, the overweight group was  $282.0 \pm 208.7$  mL, and the obese group was  $330.5 \pm 302.4$  mL in THA ( $P = 0.001$ ) and the estimated blood loss of the normal group was  $85.7 \pm 153.8$  mL, the overweight group was  $90.5 \pm 164.6$  mL, and the obese group was  $89.4 \pm 72.4$  mL in TKA ( $P = 0.001$ ) [39]. This could explain that the obese patients own greater overall blood volume physiologically and need larger exposure, need greater soft tissue dissection, and has the possibility of bleeding [39, 40].

Excessive alcohol consumption has been associated with adverse outcomes in orthopedic surgeries [41–43]. However,

there is rare research on the relationship between alcohol consumption and blood loss. We consider that alcohol consumption leads to excessive blood loss at multiple levels, for example, abnormally low platelet numbers in the blood, impaired platelet function, and impairment of fibrinolysis. Alcohol consumption can exert direct toxic effect on platelet production, survival, and function; previous studies have shown that alcohol has negative effects on platelet-platelet interaction and can produce thrombocytopenia which seems to be the commonly cause of platelet depletion [44–46].

Our study analyzes patient characteristics related to blood loss in HTO, wishing to establish application model in order to predict the risk of blood loss preoperative and guide blood management perioperative by patient characteristics.

This study has limitations: (1) It is a small retrospectively study. (2) The research is a single-center study in which all operations were performed by the same surgeons. The results may be biased and further larger, multicenter research was needed to confirm our findings.

## 5. Conclusion

Our study indicates that alcohol consumption and BMI are important risk factors related to blood loss in HTO; the surgeons can predict the risk of blood loss by evaluating patient characteristics.

## Data Availability

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

## Conflicts of Interest

The authors declare that there are no conflicts of interest to report regarding the work and publication of this study.

## References

- [1] Y. S. Kim and Y. G. Koh, "Comparative matched-pair analysis of open-wedge high tibial osteotomy with versus without an injection of adipose-derived mesenchymal stem cells for varus knee osteoarthritis: clinical and second-look arthroscopic results," *The American Journal of Sports Medicine*, vol. 46, no. 11, pp. 2669–2677, 2018.
- [2] J. Lu, S. Tang, Y. Wang et al., "Clinical outcomes of closing-and opening-wedge high tibial osteotomy for treatment of anteromedial unicompartamental knee osteoarthritis," *The journal of Knee Surgery*, vol. 32, no. 8, pp. 758–763, 2019.
- [3] G. Spahn, H. M. Klinger, P. Harth, and G. O. Hofmann, "Knorpelregeneration nach valgusierender Tibiakopfosteotomie. Ergebnisse einer arthroskopischen Studie," *Zeitschrift für Orthopädie und Unfallchirurgie*, vol. 150, no. 3, pp. 272–279, 2012.
- [4] M. S. Black, A. G. d'Entremont, R. G. McCormack, G. Hansen, D. Carr, and D. R. Wilson, "The effect of wedge and tibial slope angles on knee contact pressure and kinematics following medial opening-wedge high tibial osteotomy," *Clinical Biomechanics*, vol. 51, pp. 17–25, 2018.
- [5] X. Liu, Z. Chen, Y. Gao, J. Zhang, and Z. Jin, "High Tibial osteotomy: review of techniques and biomechanics," *Journal of Healthcare Engineering*, vol. 2019, 12 pages, 2019.
- [6] S. Akizuki, A. Shibakawa, T. Takizawa, I. Yamazaki, and H. Horiuchi, "The long-term outcome of high tibial osteotomy," *Journal of Bone and Joint Surgery. British Volume*, vol. 90-B, no. 5, pp. 592–596, 2008.
- [7] S. J. Song and D. K. Bae, "Computer-assisted navigation in high tibial osteotomy," *Clinics in Orthopedic Surgery*, vol. 8, no. 4, pp. 349–357, 2016.
- [8] M. Webb, V. Dewan, and D. Elson, "Functional results following high tibial osteotomy: a review of the literature," *European Journal of Orthopaedic Surgery & Traumatology*, vol. 28, no. 4, pp. 555–563, 2018.
- [9] D. W. Suh, B. S. Kyung, S. B. Han, K. Cheong, and W. H. Lee, "Efficacy of tranexamic acid for hemostasis in patients undergoing high tibial osteotomy," *The Journal of Knee Surgery*, vol. 31, no. 1, pp. 50–55, 2017.
- [10] S. Dragosloveanu, S. Cristea, and C. Dragosloveanu, "The effect of high tibial osteotomy on the posterior tibial slope," *Maedica*, vol. 9, no. 2, pp. 173–178, 2014.
- [11] T. B. Lind-Hansen, M. C. Lind, P. T. Nielsen, and M. B. Laursen, "Open-wedge high tibial osteotomy: RCT 2 years RSA follow-up," *The Journal of Knee Surgery*, vol. 29, no. 8, pp. 664–672, 2016.
- [12] T. Motycka, G. Eggerth, and F. Landsiedl, "The incidence of thrombosis in high tibial osteotomies with and without the use of a tourniquet," *Archives of Orthopaedic and Trauma Surgery*, vol. 120, no. 3-4, pp. 157–159, 2000.
- [13] L. Klenerman, R. Chakrabarti, I. Mackie, M. Brozovic, and Y. Stirling, "Changes in haemostatic system after application of a tourniquet," *The Lancet*, vol. 309, no. 8019, pp. 970–972, 1977.
- [14] J. Petäjä, P. Myllynen, G. Myllylä, and E. Vahtera, "Fibrinolysis after application of a pneumatic tourniquet," *Acta chirurgica scandinavica*, vol. 153, no. 11-12, pp. 647–651, 1987.
- [15] O. Reikerås and T. Clementsen, "Time course of thrombosis and fibrinolysis in total knee arthroplasty with tourniquet application. Local versus systemic activations," *Journal of Thrombosis and Thrombolysis*, vol. 28, no. 4, pp. 425–428, 2009.
- [16] A. O. Ogbemudia, A. Bafor, and L. West-Osemwengie, "Reactionary haemorrhage reduction with adrenaline infiltration in proximal tibial osteotomy: a randomized clinical study of safety and efficacy," *Archives of Orthopaedic and Trauma Surgery*, vol. 132, no. 1, pp. 21–24, 2012.
- [17] M. Munier, M. Donnez, M. Ollivier et al., "Can three-dimensional patient-specific cutting guides be used to achieve optimal correction for high tibial osteotomy? Pilot study," *Orthopaedics & Traumatology: Surgery & Research*, vol. 103, no. 2, pp. 245–250, 2017.
- [18] S. S. Seo, O. G. Kim, J. H. Seo, D. H. Kim, Y. G. Kim, and I. S. Lee, "Complications and short-term outcomes of medial opening wedge high tibial osteotomy using a locking plate for medial osteoarthritis of the knee," *Knee surgery & related research*, vol. 28, no. 4, pp. 289–296, 2016.
- [19] R. Martin, T. B. Birmingham, K. Willits, R. Litchfield, M. E. LeBel, and J. R. Giffin, "Adverse event rates and classifications in medial opening wedge high tibial osteotomy," *The American Journal of Sports Medicine*, vol. 42, no. 5, pp. 1118–1126, 2014.

- [20] G. Spahn, "Complications in high tibial (medial opening wedge) osteotomy," *Archives of Orthopaedic and Trauma Surgery*, vol. 124, no. 10, pp. 649–653, 2004.
- [21] S. B. Nadler, J. H. Hidalgo, and T. Bloch, "Prediction of blood volume in normal human adults," *Surgery*, vol. 51, no. 2, pp. 224–232, 1962.
- [22] J. B. Gross, "Estimating allowable blood loss: corrected for dilution," *Anesthesiology*, vol. 58, no. 3, pp. 277–280, 1983.
- [23] S. Vainionpää, E. Laike, P. Kirves, and P. Tiusanen, "Tibial osteotomy for osteoarthritis of the knee. A five to ten-year follow-up study," *The Journal of Bone and Joint Surgery. American Volume*, vol. 63, no. 6, pp. 938–946, 1981.
- [24] M. J. Stuart, J. N. Grace, D. M. Ilstrup, C. M. Kelly, R. A. Adams, and B. F. Morrey, "Late recurrence of varus deformity after proximal tibial osteotomy," *Clinical Orthopaedics and Related Research*, vol. 260, pp. 61–65, 1990.
- [25] A. E. Staubli, C. De Simoni, R. Babst, and P. Lobenhoffer, "TomoFix: a new LCP-concept for open wedge osteotomy of the medial proximal tibia – early results in 92 cases," *Injury*, vol. 34, pp. 55–62, 2003.
- [26] P. Niemeyer, H. Schmal, O. Hauschild, J. von Heyden, N. P. Südkamp, and W. Köstler, "Open-Wedge Osteotomy Using an Internal Plate Fixator in Patients With Medial- Compartment Gonarthrosis and Varus Malalignment: 3-Year Results With Regard to Preoperative Arthroscopic and Radiographic Findings," *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, vol. 26, no. 12, pp. 1607–1616, 2010.
- [27] P. Hernigou, D. Medevielle, J. Debeyre, and D. Goutallier, "Proximal tibial osteotomy for osteoarthritis with varus deformity. A ten to thirteen-year follow-up study," *The Journal of Bone and Joint Surgery. American Volume*, vol. 69, no. 3, pp. 332–354, 1987.
- [28] Z. Wang, Y. Zeng, W. She, X. Luo, and L. Cai, "Is opening-wedge high tibial osteotomy superior to closing-wedge high tibial osteotomy in treatment of unicompartmental osteoarthritis? A meta-analysis of randomized controlled trials," *International Journal of Surgery*, vol. 60, pp. 153–163, 2018.
- [29] H. Sun, L. Zhou, F. Li, and J. Duan, "Comparison between closing-wedge and opening-wedge high tibial osteotomy in patients with medial knee osteoarthritis: a systematic review and meta-analysis," *The journal of knee surgery*, vol. 30, no. 2, pp. 158–165, 2017.
- [30] N. van Egmond, S. van Grinsven, C. J. M. van Loon, R. D. Gaasbeek, and A. van Kampen, "Better clinical results after closed- compared to open-wedge high tibial osteotomy in patients with medial knee osteoarthritis and varus leg alignment," *Knee Surgery, Sports Traumatology, Arthroscopy*, vol. 24, no. 1, pp. 34–41, 2016.
- [31] J. Bahm, S. Sv, N. Pallua, and S. WSJJoK, "Comparison of the leg-length change between opening- and closing-wedge high tibial osteotomy: a systematic review and meta-analysis," *The Journal of Knee Surgery*, 2018.
- [32] K. I. Kim, H. J. Kim, G. B. Kim, and S. H. Bae, "Tranexamic acid is effective for blood management in open-wedge high tibial osteotomy," *Orthopaedics & Traumatology: Surgery & Research*, vol. 104, no. 7, pp. 1003–1007, 2018.
- [33] J. P. Venkatesh, S. Das, K. H. Moon, D. H. Kim, and T. K. Kim, "Intravenous tranexamic acid reduces postoperative blood loss after high tibial osteotomy," *Clinical Orthopaedics and Related Research*, vol. 476, no. 11, pp. 2148–2154, 2018.
- [34] S. Floerkemeier, A. E. Staubli, S. Schroeter, S. Goldhahn, and P. Lobenhoffer, "Outcome after high tibial open-wedge osteotomy: a retrospective evaluation of 533 patients," *Knee Surgery, Sports Traumatology, Arthroscopy*, vol. 21, no. 1, pp. 170–180, 2013.
- [35] T. Woodacre, M. Ricketts, J. T. Evans et al., "Complications associated with opening wedge high tibial osteotomy — A review of the literature and of 15 years of experience," *The Knee*, vol. 23, no. 2, pp. 276–282, 2016.
- [36] S. R. Jibodh, I. Gurkan, and J. F. Wenz, "In-hospital outcome and resource use in hip arthroplasty: influence of body mass," *Orthopedics*, vol. 27, no. 6, pp. 594–601, 2004.
- [37] J. Roué, E. De Thomasson, A.-M. Carlier, and C. Mazel, "Influence de l'indice de masse corporelle sur la réalisation d'une prothèse totale de hanche par voie d'abord antérieure réduite," *Revue de Chirurgie Orthopédique et Réparatrice de l'Appareil Moteur*, vol. 93, no. 2, pp. 165–170, 2007.
- [38] D. E. Lehman, W. N. Capello, and J. R. Feinberg, "Total hip arthroplasty without cement in obese patients. A minimum two-year clinical and radiographic follow-up study," *The Journal of bone and joint surgery. American volume*, vol. 76, no. 6, pp. 854–862, 1994.
- [39] N. Frisch, N. M. Wessell, M. Charters et al., "Effect of body mass index on blood transfusion in total hip and knee arthroplasty," *Orthopedics*, vol. 39, no. 5, pp. e844–e849, 2016.
- [40] N. L. Millar, A. H. Deakin, L. L. Millar, A. W. Kinnimonth, and F. Picard, "Blood loss following total knee replacement in the morbidly obese: effects of computer navigation," *The Knee*, vol. 18, no. 2, pp. 108–112, 2011.
- [41] C. J. Lavernia, J. M. Villa, and J. S. Contreras, "Arthroplasty knee surgery and alcohol use: risk factor or benefit?," *Clinical Orthopaedics and Related Research*, vol. 471, no. 1, pp. 189–194, 2013.
- [42] S. A. Paterno, P. F. Lachiewicz, and S. S. Kelley, "The Influence of Patient-Related Factors and the Position of the Acetabular Component on the Rate of Dislocation after Total Hip Replacement\*," *JBJS*, vol. 79, no. 8, pp. 1202–1210, 1997.
- [43] A. H. Harris, R. Reeder, L. Ellerbe, K. A. Bradley, A. D. Rubinsky, and N. J. Giori, "Preoperative alcohol screening scores: association with complications in men undergoing total joint arthroplasty," *JBJS*, vol. 93, no. 4, pp. 321–327, 2011.
- [44] D. H. Cowan, "The platelet defect in alcoholism," *Annals of the New York Academy of Sciences*, vol. 33, no. 2, pp. 310–327, 1975.
- [45] S. Peltz, "Severe thrombocytopenia secondary to alcohol use," *Postgraduate Medicine*, vol. 89, no. 6, pp. 75–76, 2016.
- [46] D. H. Cowan and J. D. Hines, "Thrombocytopenia of severe alcoholism," *Annals of Internal Medicine*, vol. 74, no. 1, pp. 37–43, 1971.