

FACTORS RELATED TO BLOOD LOSS IN TOTAL KNEE ARTHROPLASTY

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Abstract

Background: Mainly the elderly undergo total knee arthroplasty (TKA) which entails risks from medical procedures and conditions. The reported amount of blood loss in TKA varies in different studies. Blood loss from TKA may change hemodynamic status, leading to risk of cardiovascular morbidity or mortality. Allogeneic blood transfusion, associated with many immunological and transfusion complications, increase surgery costs. Controlling factors associated with blood loss should decrease blood loss and complications.

Objectives: Determining risk factors for blood loss constitute a significant step toward blood management. This study also used calculated blood loss, which is more accurate than visible blood loss.

Methods: Medical records of 517 patients undergoing TKA from 2011 to 2016 were examined, and blood loss was calculated using Gross' formula. Pearson's correlation and multiple regression analyses were used to identify factors associated with blood loss.

Results: The mean calculated blood loss decreased yearly from 602.94ml to 107.78ml in 2016 with "zero" transfusions in 2016. Radivac drain, patellar resurfacing, modified Robert Jones bandage and higher postoperative pain score related to increased blood loss after TKA according to Pearson's correlation. Multiple regression analysis revealed significant independent predictors related to blood loss included radivac drain, intravenous tranexamic acid, postoperative pain score and body mass index (BMI).

Conclusion: Awareness of low BMI patients, avoiding radivac drain use, routine using of intravenous tranexamic acid and good postoperative pain control could reduce blood loss and transfusions for patients undergoing TKA.

Keywords : Blood loss, TKA, Radivac drain, Transfusion, Tranexamic acid

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Introduction

Total knee arthroplasty (TKA) is a major orthopedic operation for advanced stage osteoarthritis of the knee. Increasing occurrence of this operation by average age of the patients has been observed, including the comorbidity and aging process, followed by increasing number of its complications. One serious complication is perioperative blood loss. Total knee arthroplasty (TKA) is an operation involving significant blood loss because of extensive soft tissue release and bone cuts, varying from 500 to 1900 ml. In all, 9.8% of cases needed postoperative blood transfusion.⁽¹⁾ Blood loss from TKA may change the hemodynamic status of patients at risk of cardiovascular morbidity or mortality. Allogeneic blood transfusion is also associated with many immunological and transfusion complications such as risk of HIV transmission and mismatch complications.⁽⁷⁾ Even autologous transfusion is presents risk, autologous donors as a group tend to be older and less healthy, thereby increasing the chance of complications during donation, and risk of unrecognized bacteremia at the time of blood collection.⁽¹³⁾ Autologous transfusion may actually lead to decreased hemoglobin levels postoperatively, resulting in transfusion of autologous blood among patients who, if they had not donated and thus lowered their hemoglobin level before surgery, would not have needed the transfusion. Autologous transfusion also causes the unnecessary waste of blood and expenses. Significant blood loss from TKA is not from perioperative or suction drain but from invisible blood loss or concealed hemorrhage. Invisible blood loss is from hemolysis, blood permeating into interstitial fluid and concealed blood in intraarticular space, can total more than 500 mL.^(2, 3) Visible blood loss seen during the intraoperative period and during the postoperative period, the suction drain accounts for approximately one half of the total amount of blood loss of each patient calculated by formula.⁽⁴⁾ Gross's formula for calculating the total blood loss is the most popular at present^(4, 6), so we choose to use this formula. The time to collect blood to calculate was from the 4th to 7th postoperative day whichever was the lowest. To reduce the risks from blood transfusion and reduce costs, would constitute the best way to reduce blood loss. We retrospectively studied our patients' data and determined factors associated with blood loss in TKA to prepare and find the best solution

to reduce blood loss among our patients.

Methods

The authors retrospectively analyzed 517 consecutive patients undergoing TKA between January 2011 and December 2016 at Phyathai 2 International Hospital. The sample size was calculated using the program G*Power 3.1.⁽²⁴⁾ The sample size totaled 189 patients (**Figures 1, 2**). The research team used purposive sampling to select the 517 patients. All patients were admitted for an elective TKA by a single experienced surgeon using a primary diagnosis of advanced osteoarthritis or rheumatoid arthritis refractory to include conservative management in the study. Patients undergoing revision arthroplasty or having another orthopedic procedure in addition to TKA during one anesthetic session, as well as patients with missing relevant clinical information were excluded from the study.

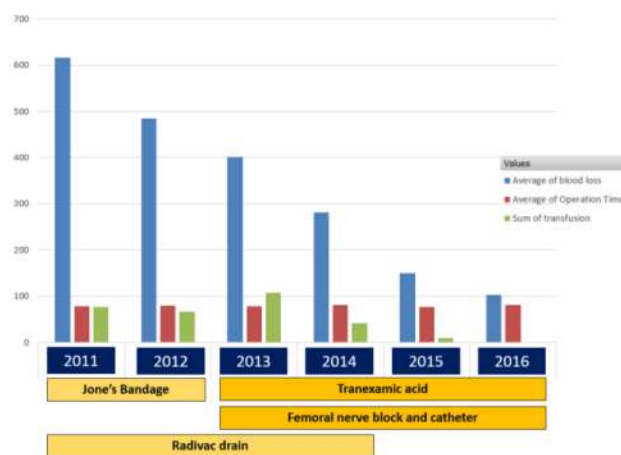


Fig 1. Trend of average blood loss reduced yearly with timeline of protocol

Data were obtained from the medical records of all patients included in the study. Data variables studied included patient demographics, body mass index (BMI), concomitant comorbidities (categorized as with or without comorbidity), length of stay, blood transfusion, preoperative hemoglobin (Hb), postoperative hemoglobin (4th day postoperative), operative times, use of drain, using of tranexamic acid, patellar resurfacing, applied modified Robert Jones bandage, postoperative pain level in the first 48 hours and femoral nerve block. The standard technique was used in all cases. The procedure was performed under spinal/epidural

anesthesia and a tourniquet was inflated 100 mmHg above the systolic blood pressure among all patients. An anterior midline skin incision and a medial parapatellar arthrotomy were performed. To reduce the intraoperative blood loss from the femoral hole, an intramedullary plug with bone grafts was used.⁽¹²⁾ The implant used was a posterior, stabilized, cemented knee prosthesis. Periarticular bupivacaine injection was performed without adding adrenaline. The tourniquet was used in all cases inflated to 350 mmHg then partially deflated to 250 mmHg after fascia closure to reduce risk of postoperative thigh pain. All patients received tranexamic acid (starting from 2013) 10 mg/kg body weight, one dose after starting anesthesia and one dose before skin closure. The antibiotic prophylaxis consisted of 2 g of cefazoline administered within 1 hour before starting the surgery and 1 g every 6 hours during the 24 hours postoperative. Among patients allergic to penicillin, we employed 1 g of vancomycin 1 hour before surgery followed by 1 g every 12 hours over 24 hours. When a radivac suction drain was inserted inside the joint it would be removed after 24 hours. Postoperative pain control was achieved by cold compression with Cryocuff, intravenous and oral NSAIDs and pregabalin the first and second postoperative days. Intravenous opioid was used when pain did not improve. The team comprising a cardiologist, orthopedist and an anesthesiologist assessed all patients postoperatively. Range of motion exercise was started on first postoperative day and full weight-bearing mobilization was started on the second day assisted by a physiotherapist. Any patient presenting a postoperative hemoglobin value of less than 8.0 g/dl received a blood transfusion.

Venous thromboembolism (VTE) prophylaxis protocol was started immediately in all cases by intermittent pneumatic compressive device and ankle pumping. Chemoprophylaxis for VTE was started the second postoperative day using oral anticoagulant (Apixaban, Rivaroxaban) for 14 days. Gross' formula was used to calculate total blood loss with hematocrit the fourth postoperative day

$$\text{Total blood loss} = \text{Blood volume} \times \left[\frac{(\text{Hct preop} - \text{Hct postop})}{\text{Hct average}} \right] + \text{ml transfused RBC}$$

Blood volume

Male: $604 + 0.0003668 \times \text{size}^3 \text{ (cm}^3\text{)} + 32.2 \times \text{weight (kg)}$

Female: $183 + 0.000356 \times \text{size}^3 \text{ (cm}^3\text{)} + 33 \times \text{weight (kg)}$

Statistical analysis

All data analyses were performed using SPSS for Windows, Version 16.0 (SPSS Inc., Chicago, IL, USA) to carry out Pearson's correlation. The size of the combined correlation coefficient (r value) reflected the degree of the relationship between an index and the other indexes, indicating the relative reliability of the method.⁽²³⁾ All values were calculated as mean ± standard deviation. A *P* value less than 0.05 was considered significant. Multiple regression analysis was used for all statistical calculations. Estimated blood loss was measured employed Gross' formula, which used the maximum postoperative decrease in the level of hemoglobin adjusted by the weight and height of the patient.⁽⁸⁾

Results

Data from 517 patients were collected from January 2011 to December 2016. Patient characteristics revealed 85% were female and 15% male. Mean age was 70±8 years old, mean BMI was 27±4 and mean operative time was 86±25 minutes. Preoperative Hb was 12.58±1.35 g/dl while postoperative Hb was 11.32±1.19 g/dl. Average calculated total blood loss was 323±243 ml. The average blood loss in each data group is summarized in **Table 1**. The trend of average blood loss decreased yearly from 2011 to 2016 as shown in graph1, i.e., 602.94 mL in 2011, 476.41 mL in 2012, 406.64 mL in 2013, 286.28 mL in 2014, 149.4 mL in 2015 and 107.78 mL in 2016. The average operative times were close, ranging from 76 to 84 minutes. The number of blood transfusion decreased to "zero" in 2016. The modified Robert Jones bandage was used from 2011 to 2012 then use stopped. The radivac drain was used from 2011 to 2013 then stopped. In addition, intravenous tranexamic acid, femoral nerve block and catheter were used from 2012. Pearson's correlation showed five factors influenced blood loss in TKA, namely, radivac drain ($r=0.452^{**}, p=0.01$), tranexamic acid ($r = -0.410^{**}, p = 0.01$), patellar resurface ($r = 0.115^{**}, p=0.01$), modified Robert Jones bandage $r=0.185^{**}, p=0.01$) and postoperative pain score ($r = 0.136^{**}, p = 0.01$). Radivac drain, patellar resurface, modified Robert Jones bandage, radivac drain, patellar resurface and postoperative pain score showed a similar trend involving blood loss, namely, more blood loss occurred when number or uses increased.

Intravenous tranexamic acid use was related to less blood loss.

Table 1. Average blood loss in each group of patients

Factors	a	b	SE.b	BETA	t	R ²	F
Constant	392.622					0.328	62.593**
X ₁ Radivac drain		196.764	18.845	.387	10.441**		
X ₂ Tranexamic acid		-163.158	18.359	-.329	-8.887**		
X ₃ Postoperative pain score		14.221	4.834	.108	2.942**		
X ₄ BMI		-4.366	1.973	-.081	-2.213*		

After employing multiple regression analysis to determine the correlation and predictive equation of blood loss, only four factors were found to influence blood loss, i.e., radivac drain ($t=10.441$, $p=0.01$), tranexamic acid ($t = -8.887$, $p = 0.01$), postoperative pain score ($t = 2.942$, $p = 0.01$) and BMI ($t = -2.213$, $p = 0.05$).

$$\text{Blood loss after TKA} = 392.622 + 196.764 X_1 - 163.158 X_2 + 14.221 X_3 - 4.366 X_4$$

Discussion

TKA is an operation involving significant blood loss, varying from 500 to 1900 ml. Approximately 9.8% of patients needed postoperative blood transfusion.⁽¹⁾ Blood loss from TKA may change the hemodynamic status of patients at risk of cardiovascular morbidity or mortality. Allogeneic blood transfusion is also associated with many immunologic and transfusion complications such as risk of HIV transmission and mismatch complications.⁽¹¹⁾ Autologous transfusion increases the chance of complications during donation, and risk of unrecognized bacteremia at the time of blood collection.⁽¹³⁾ Autologous transfusion may actually lead to decreased hemoglobin levels postoperatively, resulting in a transfusion of autologous blood among people who would not have needed a transfusion. Autologous transfusion also causes the unnecessary waste of blood and expenses.

Blood loss from TKA may change the hemodynamic status of the patient including pulse rate, respiratory rate, blood pressure and urine volume. The change of hemodynamic status depends on the severity of blood loss.⁽⁶⁾ TKA is a major orthopedic operation for advanced stage osteoarthritis of the knee. Increased average age of the patients leads to faster and more severe changes in hemodynamic status. According to advanced traumatic life support (ATLS) classification of hypovolemic shock by American college of surgeons, a blood loss of less than 750 ml (class I) does not require a blood transfusion. When we know the factors related to blood loss, we can adjust the protocol to reduce blood loss. Decreased blood loss and no blood transfusion will reduce operation costs and morbidity and mortality of patients. The results of multiple regression analysis showed four factors influencing blood loss after TKA, that is, radivac drain, tranexamic acid, postoperative pain score and BMI. Interestingly, using a radivac drain was related to increased blood loss. Kumar et al. showed that the routine use of suction drainage should be avoided after an uncomplicated total joint arthroplasty because it did not influence the incidence of wound complications and postoperative rehabilitation, thus helping to cut expenses.⁽⁹⁾ Walmsley et al. showed a lower rate of transfusion at 7% among patients not using drains.^(10,11) The American Academy of Orthopedic Surgeons (AAOS) revealed strong evidence supporting not using a drain

with TKA due to no difference in complications or outcomes. The AAOS reviewed four high quality studies and three moderate quality studies, revealing no difference in multiple measures including VTE, infection, swelling, blood transfusions, hematoma formation, range of motion, length of stay, pain or reoperation between the treatment groups. Two high quality studies reported significantly higher transfusion rates among patients who received a drain.^(20, 21) Total blood loss derives from visible and invisible blood loss. Visible blood loss is observed during the intraoperative period and during the postoperative period, the suction drain accounts for approximately one half of the total blood loss of each patient calculated by formula.⁽⁴⁾ Invisible blood loss derives from hemolysis, blood permeating into interstitial fluid and concealed blood in the intraarticular space. Wound closure without that radivac drain will conceal the created tamponade effect of the joint leading to reduced blood loss.

Many research studies have recommended the routine use of intravenous tranexamic acid to reduce intraoperative and postoperative blood loss after joint arthroplasty. Wind et al. reviewed 2,269 consecutive primary TKA among 2,069 patients over a 3.5 year period and found that tranexamic acid infusion demonstrated a significant decrease in blood transfusions ($p=0.01$).⁽¹⁴⁾ The transfusion rate without tranexamic acid was 6.5% (120/1839) but only 0.3% (1/330) with tranexamic infusion. Our data also showed a similar result.

Paul Hegarty et al. retrospectively studied 403 patients in relation to postoperative VAS and calculated blood loss using Gross' formula revealing no significant association.⁽¹⁶⁾ However, Guay et al. found a significant correlation between measured blood loss and morphine consumption from 12 to 18 hours postoperative.⁽¹⁵⁾ Our study found that 48 hours and more postoperative, VAS was related to increasing blood loss. As we know, TKA is an operation with blood loss from bone cut and soft tissue trauma. More soft tissue trauma creates more blood loss and interstitial blood accumulation, resulting in greater postoperative pain. Less pain causes increasing ability for the early range of motion exercise and ambulation, so less soft tissue swelling leads to less pain postoperatively.

Hrnack SA et al. retrospectively studied 94 TKA and 78

(total hip arthroplasty) THA cases, examining the effect of BMI, operative time (length of procedure) and anesthesia time on total blood loss. During primary TKA and primary THA obesity did not correlate with increased intraoperative blood loss.⁽¹⁷⁾ Marlin S Carling et al. studied 114 unilateral hip arthroplasty and 79 unilateral knee arthroplasty patients in a prospective observational study, calculating blood loss using Brecher's formula. Multivariate regression analysis revealed low BMI and high preoperative Hb increased the risk of excessive bleeding among knee patients, and long operation time, increased the risk of RBC transfusion.⁽¹⁹⁾

Francisco Mesa-Ramos conducted a prospective randomized study of 121 TKA also showing no correlation with BMI concerning blood transfusion after TKA.⁽¹⁸⁾ Our results showed that low BMI was related to increased blood loss which agreed with the study of Carling.⁽¹⁹⁾

The results of the study of Marlin S Carling et al. showed that long operative time increased the risk of RBC transfusion. In addition, a higher degree of intraoperative bleeding may extend surgical time and long operative time may increase bleeding over time.⁽¹⁹⁾ Our results showed no correlation between the operative time and calculated blood loss among TKA patients using both Pearson's correlation and multiple regression analysis. About 63% of our patients completed operation within 60-90 minutes under a single experience surgeon. The surgical technique might directly affect both operative time and blood loss as already discussed. A skillful surgical technique would reduce operative time, soft tissue trauma and blood loss.

Theoretically, postoperative compression dressing, modified Robert Jones bandage, can cause the tamponade effect that reduces soft tissue edema and postoperative bleeding after TKA. Pinsornsak P. et al. conducted a prospective randomized controlled trial of 60 knees in over eight months revealing no differences in mean postoperative blood loss between groups.⁽²²⁾ We discontinued using the modified Robert Jones bandage in 2012. The result from this study showed the relation of the modified Robert Jones bandage with increased blood loss revealed by Pearson's correlation and no correlation using multiple regression analysis. The results indicate no benefit of using the modified Robert Jones bandage with TKA.

Conclusion

Using Pearson's correlation, a radivac drain, patellar resurfacing, modified Robert Jones bandage and higher postoperative pain score were related to increased blood loss after TKA. Using a radivac drain was also related to increased blood loss according to multiple regression analysis. Routine use of intravenous tranexamic acid related to reduced blood loss in TKA. BMI also was related to blood loss, and patients with low BMI may need greater awareness. Increased postoperative pain score related to increased blood loss, experience of surgeon, good surgical technique and postoperative pain control were important factors in this study. Identification of risk factors will help create greater awareness of high risk patients and improve intraoperative and postoperative protocols to minimize blood loss and transfusion associated risks for patients undergoing TKA.

References

1. Evans S, O'Loughlin E, Bruce J. Retrospective audit of blood transfusion and comparison with haemoglobin concentration in patients undergoing elective primary and revision lower limb arthroplasty. *Anaesth Intensive Care* 2011; 39: 480-5.
2. Erskine JG, Fraser C, Simpson R, Protheroe K, Walker ID. Blood loss with knee joint replacement. *J R Coll Surg Edinb* 1981; 26: 295-7.
3. Chotanaphuti T, Wangwittayakul V, Khuangsirikul S. The accuracy of component alignment in custom cutting blocks compared with conventional total knee arthroplasty instrumentation: prospective control trial. *The Knee* 2014; 21: 185-8.
4. Gibon E, Courpied JP, Hamadouche M. Total joint replacement and blood loss: what is the best equation? *Int Orthop* 2013; 37: 735-9.
5. Bierbaum BE, Callaghan JJ, Galante JO, Rubash HE, Tooms RE, Welch RE. An analysis of blood management in patients having a total hip or knee arthroplasty. *J Bone Joint Surg Am* 1999; 81: 2-10.
6. Sehat KR, Evans RL, Newman JH. Hidden blood loss following hip and knee arthroplasty. Correct management of blood loss should take hidden loss into account. *J Bone Joint Surg Br* 2004; 86: 561-5.
7. Fiebig E. Safety of the blood supply. *Clin Orthop Relat Res* 1998; 357: 6-18.
8. Gross JB. Estimating allowable blood loss: corrected for dilution. *Anaesthesiology* 1983; 58: 277-80.
9. Kumar S, Penematsa S, Parekh S. Are drains required following a routine primary total joint arthroplasty? *Int Orthop* 2007; 31: 593-96.
10. Walmsley PJ, Kelly MB, Hill RM, Brenkel I. A prospective, randomised, controlled trial of the use of drains in total hip arthroplasty. *J Bone Joint Surg Br* 2005; 87: 1397-1401.
11. Kim YH, Cho SH, Kim RS. Drainage versus nondrainage in simultaneous bilateral total knee arthroplasties. *Clin Orthop Relat Res* 1998; 347: 188-93.
12. Raut VV, Stone MH, Wroblewski BM. Reduction of postoperative blood loss after press-fit condylar knee arthroplasty with use of a femoral intramedullary plug. *J Bone Joint Surg Am* 1993; 75: 1356-57.
13. Yomtovian R. Autologous transfusion complications. In *Transfusion reactions*. American Association of Blood Banks Press, Bethesda, 1996 pp 237-80.
14. Wind TC, Barfield WR, Moskal JT. The effect of tranexamic acid on blood loss and transfusion rate in primary total knee arthroplasty. *J Arthroplasty* 2013; 28: 1080-3.
15. Guay J. Postoperative pain significantly influences postoperative blood loss in patients undergoing total knee replacement. *Pain Med* 2006; 7: 476-82.
16. Hegarty P, O'Brien S, Stevenson M, Beverland D. The effect of peri-operative blood loss on postoperative pain following total knee arthroplasty. *J Orthop* 2016; 12: 47-150.
17. Hrnack SA, Skeen N, Xu T, Rosenstein AD. Correlation of body mass index and blood loss during total knee and total hip arthroplasty. *Am J Orthop (Belle Mead NJ)* 2012; 4: 467-71.
18. Mesa-Ramos F, Mesa-Ramos M. Predictors for blood transfusion following total knee arthroplasty: A prospective randomised study. *Acta Orthop Belg* 2008; 74: 83-9.
19. Carling MS, Jeppsson A, Eriksson BI, Brisby H. Transfusions and blood loss in total hip and knee arthroplasty: a prospective observational study. *J Orthop Surg Res* 2015; 10: 48.

20. Esler CAN, Blakeway C, Fiddian NJ. The use of a closed-suction drain in total knee arthroplasty. *J Bone Joint Surg Br* 2003; 2: 215-17.
21. Li C, Nijat A, Askar M. No clear advantage to use of wound drains after unilateral total knee arthroplasty: a prospective randomized, controlled trial. *J Arthroplasty* 2011; 4: 519-22.
22. Pinsornsak P, Chumchuen S. Can a modified Robert Jones bandage after knee arthroplasty reduce blood loss? A prospective randomized controlled trial. *Clin Orthop Relat Res* 2013; 471: 1677-81.
23. Chen Z. Comparative analysis, 4 calculating methods for human body surface area. *Chin J Sports Med* 2003; 22: 576-9.
24. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behav Res Methods* 2009; 41: 1149-60.