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Changes in perioperative hemoglobin and hematocrit in patients undergoing total knee arthroplasty: a prospective observational study of optimal timing of measurement

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Abstract

Objective: This study was performed to depict the patterns of change in the perioperative hemoglobin (Hb) concentration and hematocrit (Hct) and to identify the optimal timing of Hb and Hct measurement in patients undergoing total knee arthroplasty (TKA).

Methods: This prospective observational study involved 302 consecutive patients who underwent TKA. The patients were kept in hospital for 1 full week postoperatively. Hb and Hct measurements were performed preoperatively and on days 1 to 7 postoperatively and then during clinic visits at 1, 3, and 6 months postoperatively.

Results: The Hb concentration and Hct decreased during the first few days postoperatively and reached a nadir on postoperative day 4 and 3, respectively; they then recovered in the following days. Significant differences in the Hb concentration and Hct were detected between the preoperative period and day 1, between days 1 and 2, between days 2 and 3, between day 7 and 1 month, and between 1 and 3 months. A significant difference in the Hct was also detected between 3 and 6 months.

Conclusion: The optimal timing of Hb and Hct measurement is on postoperative day 3 or 4. This timing accurately reflects ongoing hidden blood loss to better guide blood transfusions.

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Total knee arthroplasty, blood loss, hemoglobin, hematocrit, transfusion, perioperative monitoring

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Introduction

Total knee arthroplasty (TKA) is a successful, safe, and cost-effective surgical procedure to relieve pain, correct deformity, and restore function in patients with end-stage knee arthritis.[1,2] However, TKA has long been associated with significant decreases in the hemoglobin (Hb) concentration and hematocrit (Hct) because of perioperative visible and hidden blood loss. In such cases, blood transfusion is not uncommon in the early postoperative period, placing patients at risk of transfusion reactions.[3] Several studies have highlighted the disadvantages of allogeneic blood transfusion, including negative effects on postoperative complications, transfusion-related complications, a prolonged hospital stay, higher cost, and higher mortality.[4–6] Current research on perioperative blood management during TKA is mostly focused on rational application of tourniquets and drainage,[7,8] meticulous operative techniques,[9] sealing of the intramedullary femoral canal,[10] and prescription of tranexamic acid (TXA) or other agents.[11] In contrast, the patterns of change in the Hb concentration and Hct after TKA have rarely been a topic of investigation, and the optimal timing of Hb and Hct measurement remains equivocal.

The fundamental target of blood management is to decrease the need for allogeneic blood transfusion while preventing anemia. The blood transfusion trigger should be individualized by weighing the risks and benefits, which should be primarily based on the patient's postoperative Hb concentration and Hct with associated medical comorbidities. Nevertheless, the Hb thresholds used to determine whether a blood transfusion is required vary significantly across the literature.[12–14] A systematic review of 10 trials identified a transfusion trigger of 7.0 to 10.0 g/dL (most commonly 8.0 or 9.0 g/dL).[15] A recent study of TKA set the criterion for blood transfusion at an Hb concentration of $<$8.0 g/dL or symptomatic anemia at $<$10.0 g/dL.[16] Current evidence suggests a restrictive transfusion threshold using a lower Hb concentration to trigger transfusion (most commonly 7.0 or 8.0 g/dL) and a liberal transfusion threshold using a higher Hb concentration to trigger transfusion (most commonly 9.0 or 10.0 g/dL).[17] Furthermore, the preoperative Hb concentration is also regarded as a predictor of postoperative transfusion, Ryan et al.[18] indicated that patients with a preoperative Hb concentration of $<$12.5 g/dL are particularly at risk and should be considered for blood conservation programs. Thus, the preoperative Hb concentration plays a significant role in transfusion, and the postoperative Hb concentration and Hct vary greatly based on the timing of sample collection.

We designed this prospective observational study to investigate the perioperative changes in the Hb concentration and Hct in patients undergoing TKA and to determine the optimal timing of sample collection to better guide the practice of blood transfusion.

Materials and methods

Study design

This prospective observational study was designed to investigate the perioperative changes in the Hb concentration and Hct and to determinate the optimal timing of sample collection in patients undergoing primary TKA surgery. In our department, patients are normally kept in hospital for 1 week after TKA; this allows for blood collection through postoperative day 7. This study was approved by the institutional ethics committee, and all recruited patients provided informed consent.

Patient selection

All consecutive patients who underwent primary TKA for treatment of knee osteoarthritis from January 2017 to December 2018 and provided consent to participate in this study were prospectively screened. The inclusion criteria were an age of >55 years, a plan to undergo unilateral TKA, and a preoperative Hb concentration of >12 g/dL (men) or 11 g/dL (women). The exclusion criteria were disorders of the blood system, such as coagulation deficiency, polycythemia, or thrombocytopenia; a history of surgery involving the ipsilateral knee joint; and the performance of an allogeneic blood transfusion or occurrence of significant complications during the study.

Perioperative management

All patients underwent TKA with the same general anesthetic protocol. Under tourniquet control, standard TKA was conducted through a midline incision and a medial parapatellar approach. All surgeries were performed by one chief surgeon using a posterior cruciate-substituting cemented prosthesis (Genesis II Oxinium; Smith & Nephew, Watford, Hertfordshire, England). One gram of intravenous TXA was administered prior to the skin incision. The procedure normally involved insertion of a drainage tube, which was then removed 24 hours postoperatively. All patients were mobilized postoperatively according to a standardized physical therapy protocol under the guidance of doctors and nurses. Routine transfusion practice was conducted according to the local institutional policy; transfusion was performed in patients with an Hb concentration of <7.0 g/dL or <9.0 g/dL with symptomatic anemia. No medication, such as erythropoietin or an iron supplement, was administered to treat anemia after TKA. Patients received an allogeneic blood transfusion if they reached the transfusion criterion.

Data assessment

Demographic information (age, sex, and body mass index) and perioperative values (operation time, intraoperative blood loss, and postoperative drainage volume) were collected and recorded. The Hb concentration and Hct were examined after admission (preoperatively) and on postoperative days 1 through 7. Whether a patient received an allogeneic blood transfusion at each time point was recorded in detail. The patients were further followed up at 1, 3, and 6 months postoperatively to screen their functional recovery and measure their Hb concentration and Hct.

Statistical analysis

Data were collected and recorded using Microsoft Excel (Office 365, 2016 version; Microsoft Corporation, Redmond, WA, USA) and analyzed using standard statistical software (IBM SPSS Statistics for Windows, Version 22.0; IBM Corp., Armonk, NY, USA). Continuous variables are presented as mean ± standard deviation, and Student's t-test was used to investigate the differences between different time points. Results were considered statistically significant at $p < 0.05$.

Results

In total, 376 patients who underwent primary unilateral TKAs during the study period were identified. After application of the inclusion and exclusion criteria, 52 patients were excluded. Perioperatively, 21 patients received an allogeneic blood transfusion according to the institutional transfusion policy, and 1 patient developed an infection and thus underwent a revision surgery; these 22 patients were also excluded. Finally, 302 patients were included in this prospective observational study. A patient flow chart is shown in Figure 1. The patients comprised 104 men and 198 women with a mean age of 71.2 years. The median preoperative Hb concentration was 13.4 (range, 11.2–16.4) g/dL, and the median preoperative Hct was 38.7% (range, 29.6% to 47.1%). The patients' demographic information is shown in Table 1.

Changes in the Hb concentration during follow-up are shown in Table 2 and Figure 2(a). The Hb concentration dramatically decreased in the early postoperative period and reached its nadir at day 4; it thereafter began to increase on day 5. At 3 months postoperatively, the Hb concentration had already recovered to 94.8% of the preoperative value and was approaching the 6-month postoperative concentration. Significant differences in the Hb concentration were detected between the preoperative period and day 1 ($p < 0.001$), between days 1 and 2 ($p = 0.018$), between days 2 and 3 ($p < 0.001$), between day 7 and 1 month ($p < 0.001$), and between 1 and 3 months ($p < 0.001$). No significant difference was found between 3 and 6 months.

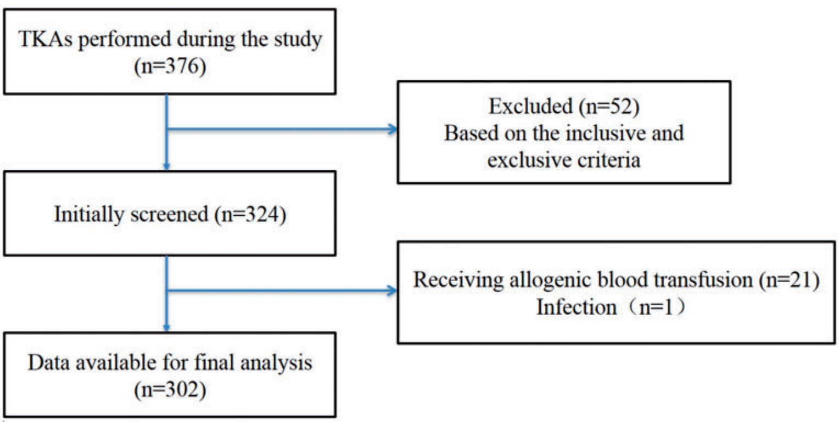

Figure 1. Patient flow chart.

Table 1. Demographic information.

Parameter	Sex (M/F)	Age (years)	BMI (kg/m^2)	Hb (g/dL)	Hct (%)	Operation time (min)	Blood loss (mL)	Drainage (mL)
Value	104/198	71.2 ± 8.6	26.7 ± 2.9	13.4 ± 1.6	38.7 ± 4.2	71.3 ± 11.8	212.6 ± 37.4	287.5 ± 49.8

Data are presented as number of patients or mean ± standard deviation.
M, male; F, female; BMI, body mass index; Hb, hemoglobin; Hct, hematocrit.

Table 2. Changes in hemoglobin concentration during follow-up.

Time point	Preoperative	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	1 Month	3 Months	6 Months
Value	13.4 ± 1.6	11.2 ± 1.5	10.7 ± 1.3	9.7 ± 1.5	9.4 ± 1.3	9.6 ± 1.4	9.9 ± 1.6	10.0 ± 1.8	11.5 ± 1.7	12.7 ± 1.6	13.1 ± 1.5
ΔValue	0	2.2 ± 0.4	2.7 ± 0.5	3.7 ± 0.6	4.0 ± 0.5	3.8 ± 0.6	3.5 ± 0.4	3.4 ± 0.6	1.9 ± 0.4	0.7 ± 0.6	0.3 ± 0.6

Data are presented as mean ± standard deviation (g/dL).

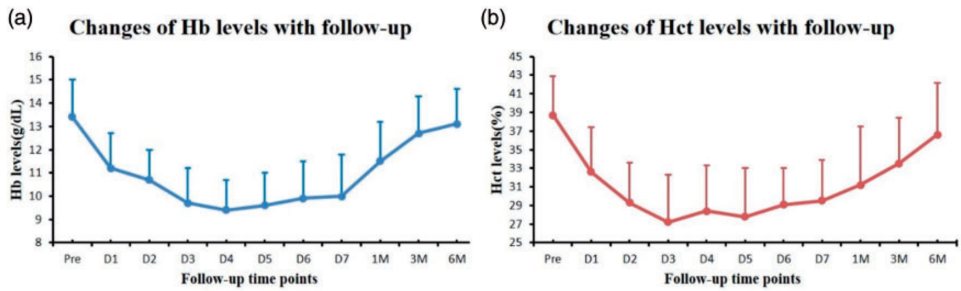

Figure 2. Changes in hemoglobin and hematocrit during follow-up.
D, day; M, month.

Table 3. Changes in hematocrit during follow-up.

Time point	Preoperative	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	1 Month	3 Months	6 Months
Value	38.7 ± 4.2	32.6 ± 4.8	29.3 ± 4.3	27.2 ± 5.1	28.4 ± 4.9	27.8 ± 5.2	29.1 ± 3.9	29.5 ± 4.4	31.2 ± 6.3	33.5 ± 4.9	36.6 ± 5.6
ΔValue	0	6.1 ± 3.2	9.4 ± 3.4	11.5 ± 3.7	10.3 ± 3.1	10.9 ± 3.6	9.6 ± 3.4	9.2 ± 3.9	7.5 ± 3.3	5.2 ± 3.7	2.1 ± 3.4

Data are presented as mean ± standard deviation (%).

Changes in the Hct during follow-up are shown in Table 3 and Figure 2(b). The Hct was significantly correlated with the Hb concentration. The Hct dramatically decreased in the first 3 days postoperatively and reached its nadir at day 3; it thereafter fluctuated on days 4 and 5 and began to increase on postoperative day 5. At 3 months postoperatively, the Hct showed a delayed recovery to 86.6% of the preoperative value in comparison with the Hb trends and reached a similar value at 6 months postoperatively. Significant differences in the Hct were detected between the preoperative period and day 1 ($p < 0.001$), between days 1 and 2 ($p < 0.001$), between days 2 and 3 ($p = 0.033$), between day 7 and 1 month ($p < 0.001$), between 1 and 3 months ($p < 0.007$), and between 3 and 6 months ($p < 0.001$).

Perioperatively, 21 patients received an allogeneic blood transfusion. Of these patients, three received a transfusion based on an Hb concentration of 7.0 to 9.0 g/dL with symptoms of anemia, and the remaining patients received a transfusion based on an Hb concentration of <7.0 g/dL. The blood transfusions were performed during the operation in three patients, on postoperative day 1 in three patients, on day 2 in two patients, on day 3 in four patients, on day 4 in five patients, and on day 6 in one patient. Thus, among the patients who required a blood transfusion, most required the transfusion according to their postoperative day 3 and 4 Hb concentrations.

Discussion

TKA is always accompanied by significant blood loss that may cause postoperative anemia. An understanding of the patterns of postoperative Hb and Hct variations is of particular importance because of the evidence between a low Hb concentration and a reduced rehabilitation capacity.[19,20] In this study, we found that the Hb concentration and Hct dramatically decreased in the early postoperative period; reached their nadirs at day 4 and day 3, respectively; and thereafter gradually recovered to the preoperative values at 3 to 6 months postoperatively. Our results indicate that the optimal timing of Hb and Hct measurement is postoperative day 3 or 4; this timing will accurately reflect ongoing hidden blood loss to better guide blood transfusions.

Total joint arthroplasty has historically been regarded as a surgical procedure with one of the highest requirements for blood transfusions. In a 1988 study, 50% of patients who underwent TKA required a blood transfusion perioperatively.[21] During the past couple of decades, medical advances have greatly lowered the need for blood transfusions in patients undergoing TKA with a transfusion rate varying from 2% to 19%.[22–24] These medical advances have involved comprehensive strategies covering the preoperative, intraoperative, and postoperative stages of TKA. Preoperative techniques have focused on the supplementation with iron therapy,[25] erythropoietin injection,[26] and discontinuation of anticoagulants.[27] Intraoperative tactics include pharmacological treatment with antithrombolytic agents such as TXA[11] and non-pharmacological methods such as tourniquet use, hypotensive anesthesia, sealing of the intramedullary femoral canal, and shortening of the operation time.[28] Postoperatively, application of autologous transfusion drains and clamping of the surgical drains at optimal time points have decreased the need for transfusion.[29,30] We implemented the above-mentioned blood salvage strategies during TKA, and the transfusion rate was 6.5% in our cohort. This low rate might have been achieved because we monitored the Hb concentration every day postoperatively.

Research focusing on the optimal timing of postoperative blood testing remains limited in the literature. In addition to visible blood loss, TKA is associated with a significant amount of hidden blood loss. A study focusing on postoperative lower limb swelling after TKA indicated that swelling was most pronounced from postoperative day 3 to 5, which was the time period most commonly representative of ongoing blood loss.[31] Thus, the Hb concentration should be monitored during that period. Another study addressed the hidden blood loss following TKA and showed that hidden blood loss represented 49% of the total measured blood loss.[32] A recent retrospective cohort analysis of 61 consecutive patients compared the Hb concentration on day 1 versus 2 after TKA and concluded that blood testing on day 2 is more likely to reflect the ongoing hidden blood loss.[33] In the present study, we prospectively observed the postoperative changes in the Hb concentration and Hct in a larger cohort and found that blood testing on postoperative day 3 or 4 might be the optimal time point to assess hidden blood loss and determine the need for blood transfusions.

Our findings are not without limitations. First, this study involved only Chinese patients from a single institution; therefore, our results may not be generalized to other racial populations worldwide. Second, the study was purely observational in design, and no comparisons could be conducted. Finally, our institutional transfusion policy involving the criterion of an Hb concentration of <7.0 g/dL needs further validation to avoid misleading transfusion practice. Despite these limitations, the present study included a large number of TKAs and revealed definite changing patterns of the Hb concentration and Hct following TKA. We propose that postoperative day 3 or 4 might be the optimal timing for Hb and Hct measurement to better guide blood transfusions.

Conclusion

In the present study, the Hb concentration and Hct dramatically decreased during the first 4 days following TKA and then gradually recovered and approached the preoperative levels at 3 months postoperatively. This pattern of change indicates that Hb and Hct measurement on postoperative day 3 or 4 may most accurately reflect ongoing hidden blood loss, thus helping to guide blood transfusions.

Data availability

The manuscript is an original work, and the preprint version has been registered online (DOI: 10.21203/rs.3.rs-18062/v1).

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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Authors' contributions

CM and KC designed the study and drafted the manuscript; CM, TN, and ZX accumulated the data; TN and ZX analyzed the data; and CM and KC proofread the manuscript for English language. All authors read and approved the final manuscript.

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