Blood transfusions in total knee arthroplasty: a retrospective analysis of a multimodal patient blood management programme

PK Chan *, YY Hwang, Amy Cheung, CH Yan, Henry Fu, Timmy Chan, WC Fung, MH Cheung, Vincent WK Chan, KY Chiu

ABSTRACT

Purpose: Transfusion is associated with increased perioperative morbidity and mortality in patients undergoing total knee arthroplasty (TKA). Patient blood management (PBM) is an evidence-based approach to maintain blood mass via haemoglobin maintenance, haemostasis optimisation, and blood loss minimisation. The aim of the present study was to assess the effectiveness of a multimodal PBM approach in our centre.

Methods: This was a single-centre retrospective study of patients who underwent primary TKA in Queen Mary Hospital in Hong Kong in 2013 or 2018, using data from the Clinical Data Analysis and Reporting System and a local joint registry database. Patient demographics, preoperative haemoglobin, length of stay, readmission, mean units of transfusion, postoperative prosthetic joint infection, and mortality data were compared between groups.

Results: In total, 262 and 215 patients underwent primary TKA in 2013 and 2018, respectively. The mean transfusion rate significantly decreased after PBM implementation (2013: 31.3%; 2018: 1.9%, P<0.001); length of stay after TKA also significantly decreased (2013: 14.49±8.10 days; 2018: 8.77±10.14 days, P<0.001). However, there were no statistically significant differences in readmission, early prosthetic joint infection, or 90-day mortality rates between the two groups.

Conclusion: Our PBM programme effectively reduced the allogeneic blood transfusion rate in patients undergoing TKA in our institution. Thus, PBM should be considered in current TKA protocols to reduce rates of transfusions and related complications.

Hong Kong Med J 2020;26:201–7
https://doi.org/10.12809/hkmj198289

[1] **PK Chan *,** FHKCOS, FHKAM (Orthopaedic Surgery)
[2] **YY Hwang,** FHKCP, FHKAM (Medicine)
[1] **A Cheung,** FHKCOS, FHKAM (Orthopaedic Surgery)
[1] **CH Yan,** FHKCOS, FHKAM (Orthopaedic Surgery)
[1] **H Fu,** FHKCOS, FHKAM (Orthopaedic Surgery)
[3] **T Chan,** FHKCA, FHKAM (Anaesthesiology)
[1] **WC Fung,** BSc
[1] **MH Cheung,** FHKCOS, FHKAM (Orthopaedic Surgery)
[1] **VWK Chan,** FHKCOS, FHKAM (Orthopaedic Surgery)
[1] **KY Chiu** FHKCOS, FHKAM (Orthopaedic Surgery)

[1] *Department of Orthopaedics and Traumatology, Queen Mary Hospital, The University of Hong Kong, Hong Kong*
[2] *Department of Medicine, Queen Mary Hospital, Hong Kong*
[3] *Department of Anaesthesiology, Queen Mary Hospital, Hong Kong*

* Corresponding author: cpk464@yahoo.com.hk

This article was published on 6 May 2020 at www.hkmj.org.

New knowledge added by this study

- Patient blood management effectively reduced the allogeneic blood transfusion rate in patients undergoing total knee arthroplasty in our institution; it also reduced the length of stay after total knee arthroplasty.

Implications for clinical practice or policy

- Patient blood management should be considered in current total knee arthroplasty protocols to reduce rates of transfusions and related complications.
- Patient blood management in total knee arthroplasty could reduce healthcare expenditures among the ageing population in Hong Kong.

Introduction

Total knee arthroplasty (TKA) is the most effective and efficacious surgical method to improve pain and function for patients with end-stage osteoarthritis; however, TKA has been associated with substantial blood loss. In addition to visible blood loss from the surgical field and wound drainage, hidden blood loss occurred in patients undergoing TKA, which resulted in mean blood loss of 1.5 L.[1] Therefore, perioperative blood transfusion was needed in up to 38% of patients undergoing TKA.[2]

Blood transfusion is not risk-free. Often, no adverse effects are encountered by patients who undergo blood transfusion. However, adverse effects occasionally occur, ranging from minor allergic reactions to blood-borne infection and potentially fatal acute immune haemolytic reaction. With the implementation of best international practices

全膝關節置換術中輸血：多模式患者血液管理程序回顧分析

陳秉強、黃宇欣、張炎鈴、忻振凱、傅俊謙、陳智榮、馮穎釗、張文康、陳偉鈞、曲廣運

目的：進行全膝關節置換術（TKA）的患者，其輸血與圍手術期發病率和死亡率增加相關。患者血液管理（PBM）是一種循證方法，可通過維持血紅蛋白、優化止血和盡量減少失血來維持血液質量。本研究旨在評估我們中心採用多模式PBM的有效性。

方法：使用醫管局臨床數據分析及匯報系統和本地關節置換登記中心的數據，對2013年或2018年在香港瑪麗醫院接受原發性TKA的患者進行單中心回顧研究。比較兩組患者的人口統計學、術前血紅蛋白、住院時間、再入院率、平均輸血量、術後假體關節感染以及死亡率數據。

結果：2013年和2018年分別有262和215例患者接受原發性TKA。實施PBM後的平均輸血率顯著下降（2013年：31.3%；2018年：1.9%，P<0.001）;TKA後的住院時間也顯著減少（2013年：14.49±8.10天；2018年：8.77±10.14天，P<0.001）。然而，兩組在再入院、術後早期假體關節感染或90天死亡率方面無統計學差異。

結論：我們的PBM計劃能有效降低我們中心接受TKA患者的異體輸血率。因此，應在當前TKA方案中考慮PBM，以減少輸血和相關併發症的發生率。

to warrant blood transfusion safety by the Blood Transfusion Service in Hong Kong, the transfusion risk has significantly decreased in the past two decades.[3] However, absolute safety in transfusion cannot be achieved because of the window period for detecting infections, possibility of emerging infections, and potential human errors related to the process of transferring collected blood from donors to transfusion recipients. Notably, researchers in Hong Kong reported the first two cases (worldwide) of transmission of Japanese encephalitis virus, via blood transfusion to immunocompromised hosts, in 2018.[4] In addition to the general risks associated with transfusion, blood transfusion has been independently associated with poor surgical outcome. Specifically, patients who underwent transfusion exhibited an eight-fold to 10-fold excess risk of adverse outcomes, defined as postoperative complications in the American College of Surgeons National Surgical Quality Improvement Project.[5] With respect to total hip or knee arthroplasty, a dose-dependent relationship between transfusion and risk of surgical site infection was observed.[6]

With increasing understanding regarding the benefits and risks of blood transfusion, as well as alternative approaches for patients who experience blood loss, the concept of patient blood management (PBM) was developed. The World Health Organization defines PBM as 'a patient-focused, evidence-based and systematic approach to optimise the management of patients and transfusion of blood products for quality and effective patient care. It is designed to improve patient outcomes through the safe and rational use of blood and blood products and by minimising unnecessary exposure to blood products...'.[7] The three major components of PBM are as follows: (1) optimisation of the patient's own blood mass; (2) minimisation of blood loss; and (3) optimisation of physiological tolerance to anaemia.[8] This new standard of care is now well-established in some centres in the US, Austria, and Western Australia, as well as nationally in the Netherlands. However, PBM remains an uncommon practice in Asia.

We introduced the PBM programme for patients undergoing TKA in our institution, beginning in 2014. Various components were introduced gradually (in phases) from 2014 to 2018. The key measures of PBM in preoperative, intra-operative, and postoperative periods were fully implemented in 2018. To the best of our knowledge, our PBM programme is a pioneer PBM programme in Hong Kong. The aim of the present study was to assess the effectiveness of the multimodal PBM approach in our university-based centre.

Methods

This single-centre retrospective study was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (Ref UW 19-600). The requirement for patient consent was waived by the review board. We retrospectively collected blood transfusion data regarding patients who underwent unilateral primary TKA in our centre from 1 January 2013 to 31 December 2018. Patients who underwent one-stage bilateral primary TKA or revision TKA were excluded from our study. Patients with acquired or congenital coagulopathy, as well as those currently taking anticoagulants, were included in our study; notably, these patients were at greater risk of perioperative blood loss and transfusion.

The primary outcome measure was the mean yearly transfusion rate, which was defined as the number of patients who received transfusion after TKA (during the same hospitalisation episode) divided by the number of patients who underwent TKA during the period from 1 January to 31 December; this result was multiplied by 100. The mean units of blood given per transfusion episode in 1 year was defined as the cumulative total number of blood units transfused to patients after TKA in 1 year divided by the number of transfusion episodes in that year. Transfusion data were retrieved from the Clinical Data Analysis and Reporting System, a database developed by the Hong Kong Hospital Authority for research purposes; this database contains medical information recorded by the Hong Kong Hospital Authority since 1993.

Secondary outcome measures were mean length of hospital stay after surgery, the rate of unexpected readmission through the Emergency Department after discharge from the hospital, the proportion of patients who had early prosthetic joint infection requiring revision surgery within 90 days after index surgery, and the 90-day mortality rate. These data and other patient demographic data (eg, age and sex), perioperative data (eg, American Society of Anesthesiologists [ASA] physical status), and preoperative haemoglobin level were retrieved from our patient records, as well as a local joint replacement registry.

Patient blood management was a relatively new concept in Hong Kong when it was first implemented in our institution in 2014. Initially, this programme was a standalone surgeon-initiated programme without external support; it was implemented in sequential stages based on PBM guidelines provided by the National Blood Authority in Australia.[9] The sequential stages of PBM implementation in our centre are described in Table 1. The PBM strategies included modern surgical, anaesthetic, and perioperative care. In 2014, PBM was initiated with instructions regarding proper indications for transfusion, single-unit transfusion policy,[10] and restrictive transfusion policy with transfusion triggered at haemoglobin ≤8 g/dL in healthy individuals.[11] In 2015, the traditional practice of routine placement of a surgical drain during TKA (associated with a higher transfusion rate[12]) was stopped; the use of topical tranexamic acid (injection of 1 g tranexamic acid into knee joint at the end of the surgical procedure, shown to reduce postoperative blood loss and transfusion rate[13]) was implemented to reduce perioperative blood loss. In 2016, preoperative anaemia screening and optimisation were initiated via collaboration with haematologists. Patients with preoperative haemoglobin <11 g/dL were examined for causes of anaemia, in accordance with Network for Advancement of Transfusion Alternatives guidelines[14]; their erythropoiesis and preoperative haemoglobin characteristics were optimised before TKA was performed. For example, patients with iron-deficiency anaemia were checked for gastrointestinal blood loss and prescribed iron supplementation; their haemoglobin levels were rechecked after supplementation to confirm achievement of ≥11 g/dL before TKA. To further reduce intra-operative blood loss, combined intravenous tranexamic acid (15 mg/kg administered intravenously at the induction of anaesthesia) and topical tranexamic acid were implemented; these are reportedly effective for reduction of blood loss.[15] In 2017, a more stringent restrictive transfusion policy was adopted with transfusion triggered at haemoglobin ≤7 g/dL in healthy individuals. Moreover, active warming (a modern anaesthetic technique used during intra-operative care) was implemented to avoid intra-operative hypothermia[16]; this hypothermia has been associated with greater volume of blood loss and the need for transfusion.[17,18] By the beginning of 2018, all above PBM strategies were fully implemented.

TABLE 1. Summary of the gradual introduction of key components of patient blood management from 2014 to 2018

Year	PBM strategies introduced
2014	• Instructions regarding proper indications for transfusion • Single-unit transfusion policy • Restrictive transfusion policy with transfusion triggered at haemoglobin ≤8 g/dL in healthy individuals
2015	• Discontinuation of routine placement of surgical drain in TKA • Use of topical tranexamic acid
2016	• Preoperative anaemia screening and optimisation • Use of combined intravenous and topical tranexamic acid
2017	• More stringent restrictive transfusion policy with transfusion triggered at haemoglobin ≤7 g/dL in healthy individuals • Active warming to avoid intra-operative hypothermia
2018	• Full implementation

Abbreviations: PBM = patient blood management; TKA = total knee arthroplasty

In addition to PBM strategies, other changes in patient selection and perioperative management were implemented between 2013 and 2018. First, the degree of medical co-morbidities may have differed because of the establishment of another joint replacement centre in July 2016; this new centre provided joint replacement surgeries for patients with improved medical fitness, among patients with end-stage osteoarthritis in our hospital. Therefore, the medical co-morbidities of the patients in 2013 and 2018 were compared on the basis of ASA status. Second, because of technological advances in the design of TKA prostheses over time, there were differences in the numbers of modern-design TKA prostheses between 2013 and 2018; these modern-design TKA prostheses aimed to improve knee kinematics, rather than reduce transfusion rate. However, these prostheses were unlikely to bias our transfusion rate results, according to a prior assessment of factors predictive of transfusion rate in patients undergoing TKA.[19]

In 2013, no PBM strategies had been implemented in our institution, whereas all strategies had been fully implemented by 2018. The Chi squared test was used to compare the transfusion rate between patients who underwent TKA in 2013 and those who underwent TKA in 2018; differences with $P<0.05$ were considered statistically significant. As mentioned above, medical co-morbidities of the patients in 2013 and 2018 were compared on the basis of ASA status.

Results

In total, 262 and 215 patients underwent primary TKA in our centre in 2013 and 2018, respectively (Table 2). There were no significant differences in mean age (2013: 72.17±9.76 years; 2018: 72.49±9.27 years, P=0.71) or sex (male:female) ratio (2013, 61:201; 2018, 63:152, P=0.14) between the groups. The preoperative haemoglobin level was also similar between the groups (2013: 12.77±1.42 g/dL; 2018: 12.89±1.42 g/dL, P=0.35). However, there was a significant difference in ASA distribution between the groups (P=0.03). There was a comparatively greater proportion of patients with ASA Grade II status in 2018 (2013: 57.6%; 2018: 68.8%).

TABLE 2. Preoperative and postoperative parameters of patients who underwent primary TKA in Queen Mary Hospital (Hong Kong) in 2013 and 2018*

	2013	2018	P value
Preoperative parameters			
No. of unilateral TKA	262	215	
Age (years)	72.17 ± 9.76	72.49 ± 9.27	0.71
Sex, male:female	61:201	63:152	0.14
ASA status			0.03
Grade I	5.3%	2.8%	
Grade II	57.6%	68.8%	
Grade III	37.0%	28.4%	
Haemoglobin (g/dL)	12.77 ± 1.42	12.89 ± 1.42	0.35
Postoperative parameters			
Mean transfusion rate	31.3%	1.9%	<0.001
Units of blood transfusion/ transfusion episode	1.62 ± 0.78	1.00 ± 0.00	0.12
Length of stay (days)	14.49 ± 8.10	8.77 ± 10.14	<0.001
Readmission rate	3.8%	3.7%	0.96
Early prosthetic joint infection rate (within 90 days after index surgery)	0.4%	0%	0.36
90-Day mortality rate	0%	0.5%	0.27

Abbreviations: ASA = American Society of Anesthesiologists; TKA = total knee arthroplasty

* Data are shown as No., % or mean ± standard deviation, unless otherwise specified

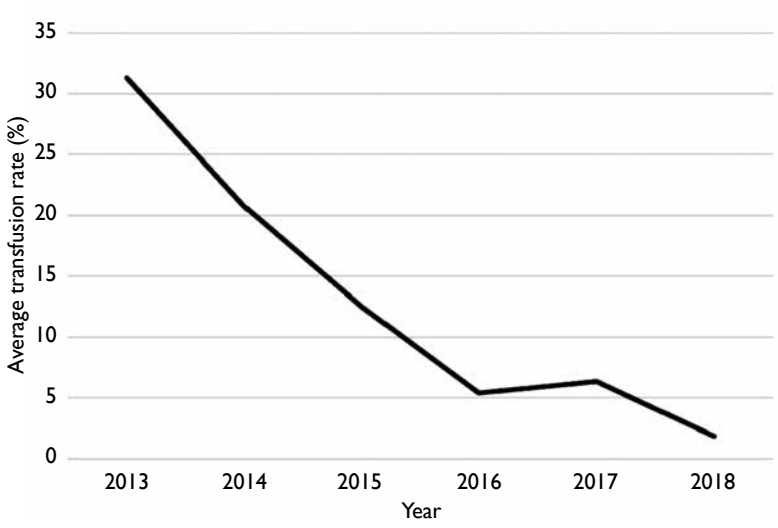

FIG. Mean annual transfusion rate among patients who underwent primary total knee arthroplasty in Queen Mary Hospital (Hong Kong)

The primary outcome was the mean transfusion rate in 1 year. There was a significant difference in the mean transfusion rate after primary TKA between 2013 and 2018 (2013: 31.3%; 2018: 1.9%, P<0.001); however, there was no significant difference in the mean units of blood transfused per transfusion episode (2013: 1.62±0.78; 2018: 1.00±0.00, P=0.12). Moreover, the mean annual transfusion rate after primary TKA exhibited stepwise reduction as PBM strategies were implemented during the period from 2014 to 2018 (Fig).

Regarding secondary outcomes, the mean length of hospitalisation was significantly lower in 2018 (2013: 14.49±8.10 days; 2018: 8.77±10.14 days, P<0.001). However, there was no difference in the unexpected readmission rate through the Emergency Department (2013: 3.8%; 2018: 3.7%, P=0.96), the proportion of patients who exhibited early prosthetic joint infection within 90 days after index surgery (2013: 0.4%; 2018: 0%, P=0.36), or the proportion of patients with 90-day mortality (2013: 0%; 2018: 0.5%, P=0.27).

Discussion

Blood transfusion is a life-saving therapy, but is a limited resource. In recent years, there have been recurrent blood shortages in Hong Kong, and the Hong Kong Red Cross has issued an urgent appeal for blood donors on several occasions.[20-23] The amount of blood stored in blood banks is determined by supply and demand. To increase blood supply, additional blood donors are needed. The Annual Report of Hong Kong Red Cross in 2018/2019 revealed that 4% of blood donors were aged >60 years, and the largest group of blood donors were aged 41-50 years (23.7% of donors).[24] With the increasing number of older people in Hong Kong, more blood donors are needed from older age-groups. In addition, healthcare professionals should be judicious in prescribing transfusion, and should consider methods to minimise transfusion. Our study demonstrated the effectiveness of implementing PBM in our centre. In addition to comparing the mean transfusion rate in 2013 and 2018, this study included an audit of the mean annual transfusion rate after primary TKA from 2014 to 2018 (Fig).

Globally, PBM is not a new concept. In May 2010, the World Health Organization formally recognised the importance of PBM and recommended its use to the 193 member states.[25] Subsequently, PBM

has been successfully implemented in Western countries, especially Australia[26] and the US.[27] The Asia-Pacific PBM Expert Consensus Meeting Working Group assessed the status of PBM in Asia.[28] In Singapore, PBM was implemented nationally, beginning in 2013. The Ministry of Health and Blood Services Group actively promoted PBM at public hospitals in the first few years; regular national audits of PBM-related efforts have been performed since 2017 to promote appropriate use of red blood cell transfusion and implementation of preoperative anaemia screening for elective surgeries. Patient blood management programmes were successfully implemented in National University Hospital and Singapore General Hospital.[28,29] In Korea, PBM was implemented through a professional initiative by the Korean Research Society of Transfusion Alternatives of the Republic of Korea in 2006; the Korean Patient Blood Management Research Group was formed to promote greater PBM use in 2016. The efforts of the Korean Patient Blood Management Research Group resulted in achievement of several PBM milestones in 2016.[28] Notably, PBM was included in the Korean Transfusion Guidelines; a new steering committee was also formed, comprising leading physicians from various specialties. Patient blood management was successfully implemented in a number of Korean hospitals, which led to a reduction in transfusion rate.[30-32] In Malaysia, PBM has been promoted at the local hospital level.[28] In the Department of Maternal and Fetal Medicine at the Sultan Haji Ahmad Shah Hospital, women at high risk of anaemia are screened for iron deficiency anaemia in early pregnancy; iron-deficient women are provided oral or intravenous iron supplementation.

At our institution, PBM was first implemented in 2014 as a surgeons' initiative in the Division of Joint Replacement Surgery. In addition to good surgical techniques, good perioperative care is an important determinant of surgical outcomes. Patient blood management is a component of our overall perioperative management protocol in the modern enhanced recovery after surgery programme. With implementation of PBM strategies and measures in the enhanced recovery after surgery programme, the length of hospitalisation was shortened in 2018, compared with 2013. Despite the shorter length of stay, there were no differences in the unexpected readmission rate through the Emergency Department, the proportion of patients who had early prosthetic joint infection within 90 days after index surgery, or the proportion of patients who had 90-day mortality.

To the best of our knowledge, there have been few studies regarding PBM in patients undergoing TKA in Hong Kong. In 2015, Lee et al[33] reported their pioneering experience with implementation of PBM in patients undergoing TKA; their PBM protocols included typing and screening only for patients with preoperative haemoglobin of <11 g/dL, and restrictive transfusion triggered at haemoglobin 8 g/dL. When they compared outcomes before and after introduction of the PBM programme, the transfusion rate (before: 10.3%; after: 3.1%, P=0.046) and cross-match rate (before: 100%; after: 3.1%, P<0.001) both decreased. We implemented PBM in our institution, beginning in 2014. Modern surgical, anaesthetic, and perioperative techniques in PBM were gradually introduced from 2014 to 2018. Our PBM protocols are more comprehensive than those of Lee et al, because our protocols were designed in accordance with the PBM guidelines provided by the National Blood Authority in Australia.[9] Therefore, our transfusion rate in TKA in 2018 decreased to 1.9%.

Prosthetic joint infection is a severe complication in arthroplasty; affected patients often require revision surgery. Notably, patients who underwent treatment for prosthetic joint infection exhibited a significant, independent risk of increased mortality, due to the direct adverse effect of infection and the indirect effect of poor underlying health condition.[34] In a recent meta-analysis involving 21 770 patients who underwent total hip and knee arthroplasty, patients who received allogeneic blood transfusion had a significantly greater risk of surgical-site infection (pooled odds ratio: 1.71, P=0.02).[35] Recently, a dose-dependent relationship was observed between allogeneic transfusion and surgical site infection after total hip or knee arthroplasty.[6] Therefore, PBM was expected to reduce the incidence of surgical site infection in our centre. However, because of the relatively small sample size in our study and the relatively low incidence of prosthetic joint infection (approximately 1%), a difference in the incidence of prosthetic joint infection between 2013 and 2018 could not be identified. When PBM was fully implemented in our centre (2018), the transfusion rate after primary TKA was 1.9%; this was comparable to international reported values. Specifically, when PBM strategies were implemented in the US, the transfusion rates were approximately 4.5%.[36] When PBM is implemented by high-volume surgeons with an eight-step checklist to reduce bleeding, the transfusion rate after TKA could be as low as 0.0044%.[37] Therefore, a transfusion rate of 0% is achievable.

As the transfusion rate decreased in patients undergoing TKA, there were also benefits to the healthcare system. Blood transfusion involves many costs associated with blood transfer from donors to recipients (eg, collection, screening, storage, transportation, and prescription of donated blood). We do not have data regarding the cost of packed red blood cells in Hong Kong; however, the cost was estimated to be approximately 1130 USD/unit in a study conducted in the US.[36] Therefore, reduced

transfusions through implementation of PBM can result in lower healthcare expenditures, which are of considerable importance because of the increasing demand for TKA among the aging population in Hong Kong.

There were some limitations in this study. First, it was a retrospective study; thus, compliance with PBM strategies could not be fully verified. However, as each strategy was introduced throughout the course of the study, there was gradual reduction in the transfusion rate. Therefore, compliance with the strategies was presumably optimal. Second, because different strategies were implemented successively, the strategies with the greatest contribution to the reduced transfusion rate could not be identified. Third, because this was not a prospective randomised placebo-controlled interventional trial, a causal relationship between PBM strategies and reduction in transfusion rate could not be established. However, our study provided an assessment of real-world implementation of PBM strategies within a large hospital; thus, it comprises pioneering research in Hong Kong. Fourth, some potential cofounding factors may not have been identified or controlled in the present analysis. For example, the type of prosthesis used was not analysed as a separate factor. However, preoperative haemoglobin levels (the most significant predictor of blood transfusion[19]) were compared between both groups. To the best of our knowledge, there remains minimal relevant literature regarding the effect of TKA prosthesis on the transfusion rate.

In conclusion, our results demonstrated the effectiveness of PBM implementation on transfusion rate in patients undergoing TKA. From 2014 to 2018, there was a stepwise reduction in transfusion rate after TKA; this was similar to findings in previously published research. This is one of the few studies in Hong Kong to review PBM in surgical practice. Although we focused on patients undergoing TKA, the principles of PBM could be useful for other medical or surgical specialties.

Author contributions

All authors contributed to the concept or design of the study, acquisition of data, analysis or interpretation of data, drafting of the manuscript, and critical revision of the manuscript for important intellectual content.

All authors had full access to the data, contributed to the study, approved the final version for publication, and take responsibility for its accuracy and integrity.

Conflicts of interest

All authors have disclosed no conflicts of interest.

Acknowledgements

We thank Dr CK Lee, Chief Executive and Medical Director, Hong Kong Red Cross Blood Transfusion Service, Hong Kong, for providing advice on the patient blood management programme. We also acknowledge and express our gratitude to the following departments of our hospital for the support in this multidisciplinary project: Nursing Division, Department of Orthopaedics and Traumatology; Operation Theatre Services; and Blood Transfusion Committee.

Declaration

This research has been presented in part as an oral presentation at the Hong Kong Hospital Authority Convention 2018.

Funding/support

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethics approval

This study was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (Ref UW 19-600). The requirement for patient consent was waived by the review board.

References

1. Sehat KR, Evans R, Newman JH. How much blood is really lost in total knee arthroplasty? Correct blood loss management should take hidden loss into account. Knee 2000;7:151-5.
2. Cushner FD, Friedman RJ. Blood loss in total knee arthroplasty. Clin Orthop Relat Res 1991;(269):98-101.
3. Lee CK. Risk minimization in transfusion transmitted infection in Hong Kong [thesis]. University of Hong Kong; 2017.
4. Cheng VC, Sridhar S, Wong SC, et al. Japanese encephalitis virus transmitted via blood transfusion, Hong Kong, China. Emerg Infect Dis 2018;24:49-57.
5. Ferraris VA, Hochstetler M, Martin JT, Mahan A, Saha SP. Blood transfusion and adverse surgical outcomes: the good and the bad. Surgery 2015;158:608-17.
6. Everhart JS, Sojka JH, Mayerson JL, Glassman AH, Scharschmidt TJ. Perioperative allogeneic red blood-cell transfusion associated with surgical site infection after total hip and knee arthroplasty. J Bone Joint Surg Am 2018;100:288-94.
7. World Health Organization. WHO Global Forum for Blood Safety: patient blood management. Available from: https://www.who.int/bloodsafety/events/gfbs_01_pbm/en/ Accessed 5 Jan 2020.
8. Isbister JP. The three-pillar matrix of patient blood management—an overview. Best Pract Res Clin Anaesthesiol 2013;27:69-84.
9. National Blood Authority Australia. Patient Blood Management Guidelines. Available from: https://www.blood.gov.au/pbm-guidelines. Accessed 9 Jan 2020.
10. National Blood Authority Australia. Single Unit Transfusion Guide. Available from: https://www.blood.gov.au/single-unit-transfusion. Accessed 9 Jan 2020.
11. Hardy JF. Current status of transfusion triggers for red blood cell concentrates. Transfus Apher Sci 2004;31:55-66.
12. Zhang Q, Liu L, Sun W, et al. Are closed suction drains necessary for primary total knee arthroplasty? A systematic review and meta-analysis. Medicine (Baltimore) 2018;97:e11290.

13. Panteli M, Papakostidis C, Dahabreh Z, Giannoudis PV. Topical tranexamic acid in total knee replacement: a systematic review and meta-analysis. Knee 2013;20:300-9.
14. Goodnough LT, Maniatis A, Earnshaw P, et al. Detection, evaluation, and management of preoperative anaemia in the elective orthopaedic surgical patient: NATA guidelines. Br J Anaesth 2011;106:13-22.
15. Shang J, Wang H, Zheng B, Rui M, Wang Y. Combined intravenous and topical tranexamic acid versus intravenous use alone in primary total knee and hip arthroplasty: A meta-analysis of randomized controlled trials. Int J Surg 2016;36:324-9.
16. Benson EE, McMillan DE, Ong B. The effects of active warming on patient temperature and pain after total knee arthroplasty. Am J Nurs 2012;112:26-33.
17. Rajagopalan S, Mascha E, Na J, Sessler DI. The effects of mild perioperative hypothermia on blood loss and transfusion requirement. Anesthesiology 2008;108:71-7.
18. Schmied H, Kurz A, Sessler DI, Kozek S, Reiter A. Mild hypothermia increases blood loss and transfusion requirements during total hip arthroplasty. Lancet 1996;347:289-92.
19. Boutsiadis A, Reynolds RJ, Saffarini M, Panisset JC. Factors that influence blood loss and need for transfusion following total knee arthroplasty. Ann Transl Med 2017;5:418.
20. Ernest K. Hong Kong Red Cross issues urgent appeal for blood donors as supplies dwindle. South China Morning Post [newspaper on the internet]. 2017 May 4: Health & Environment. Available from: https://www.scmp.com/news/hong-kong/health-environment/article/2092982/hong-kong-red-cross-issues-urgent-appeal-blood. Accessed 10 Mar 2020.
21. City urged to donate blood amid severe shortage. The Standard [newspaper on the internet]. 2017 Aug 11: Local. Available from: https://www.thestandard.com.hk/breaking-news/section/3/94995/City-urged-to-donate-blood-amid-severe-shortage. Accessed 10 Mar 2020.
22. The Government of the Hong Kong Special Administrative Region. Urgent appeal for blood donation [press release]. 2018 Jan 9. Available from: https://www.info.gov.hk/gia/general/201801/09/P2018010900651.htm. Accessed 10 Mar 2020.
23. Coronavirus fears drain Hong Kong's blood banks. Radio Television Hong Kong [newspaper on the internet]. 2020 Feb 12. Available from: https://news.rthk.hk/rthk/en/component/k2/1508174-20200212.htm. Accessed 10 Mar 2020.
24. The Annual Report of Hong Kong Red Cross 2018/2019. Available from: https://www.redcross.org.hk/en/publications/annual_reports.html. Accessed 15 Jan 2020.
25. World Health Assembly. Resolution WHA63.12: Availability, safety and quality of blood products. Available from: https://apps.who.int/medicinedocs/documents/s19998en/s19998en.pdf. Accessed 10 Jan 2020.
26. Farmer SL, Towler SC, Leahy MF, Hofmann A. Drivers for change: Western Australia Patient Blood Management Program (WA PBMP), World Health Assembly (WHA) and Advisory Committee on Blood Safety and Availability (ACBSA). Best Pract Res Clin Anaesthesiol 2013;27:43-58.
27. Whitaker B, Rajbhandary S, Kleinman S, Harris A, Kamani N. Trends in United States blood collection and transfusion: results from the 2013 AABB Blood Collection, Utilization, and Patient Blood Management Survey. Transfusion 2016;56:2173-83.
28. Abdullah HR, Ang AL, Froessler B, et al. Getting patient blood management Pillar 1 right in the Asia-Pacific: a call for action. Singapore Med J 2019 May 2. Epub ahead of print.
29. D E H O, Hadi F, Stevens V. Health economic evaluation comparing iv iron ferric carboxymaltose, iron sucrose and blood transfusion for treatment of patients with iron deficiency anemia (Ida) in Singapore. Value Health 2014;17:A784.
30. Lee ES, Kim MJ, Park BR, et al. Avoiding unnecessary blood transfusions in women with profound anaemia. Aust N Z J Obstet Gynaecol 2015;55:262-7.
31. Yoon HM, Kim YW, Nam BH, et al. Intravenous iron supplementation may be superior to observation in acute isovolemic anemia after gastrectomy for cancer. World J Gastroenterol 2014;20:1852-7.
32. Na HS, Shin SY, Hwang JY, Jeon YT, Kim CS, Do SH. Effects of intravenous iron combined with low-dose recombinant human erythropoietin on transfusion requirements in iron-deficient patients undergoing bilateral total knee replacement arthroplasty. Transfusion 2011;51:118-24.
33. Lee QJ, Mak WP, Yeung ST, Wong YC, Wai YL. Blood management protocol for total knee arthroplasty to reduce blood wastage and unnecessary transfusion. J Orthop Surg (Hong Kong) 2015;23:66-70.
34. Zmistowski B, Karam JA, Durinka JB, Casper DS, Parvizi J. Periprosthetic joint infection increases the risk of one-year mortality. J Bone Joint Surg Am 2013;95:2177-84.
35. Kim JL, Park JH, Han SB, Cho IY, Jang KM. Allogeneic blood transfusion is a significant risk factor for surgical-site infection following total hip and knee arthroplasty: a meta-analysis. J Arthroplasty 2017;32:320-5.
36. Moskal JT, Harris RN, Capps SG. Transfusion cost savings with tranexamic acid in primary total knee arthroplasty from 2009 to 2012. J Arthroplasty 2015;30:365-8.
37. Lindman IS, Carlsson LV. Extremely low transfusion rates: contemporary primary total hip and knee arthroplasties. J Arthroplasty 2018;33:51-4.