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GENERAL ORTHOPAEDICS

Transfusion in orthopaedic surgery

A RETROSPECTIVE MULTICENTRE COHORT STUDY

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Aims
Orthopaedic surgeries are complex, frequently performed procedures associated with significant haemorrhage and perioperative blood transfusion. Given refinements in surgical techniques and changes to transfusion practices, we aim to describe contemporary transfusion practices in orthopaedic surgery in order to inform perioperative planning and blood banking requirements.

Methods
We performed a retrospective cohort study of adult patients who underwent orthopaedic surgery at four Canadian hospitals between 2014 and 2016. We studied all patients admitted to hospital for nonarthroscopic joint surgeries, amputations, and fracture surgeries. For each surgery and surgical subgroup, we characterized the proportion of patients who received red blood cell (RBC) transfusion, the mean/median number of RBC units transfused, and exposure to platelets and plasma.

Results
Of the 14,584 included patients, the most commonly performed surgeries were knee arthroplasty (24.8%), hip arthroplasty (24.6%), and hip fracture surgery (17.4%). A total of 10.3% of patients received RBC transfusion; the proportion of patients receiving RBC transfusions varied widely based on the surgical subgroup (0.0% to 33.1%). Primary knee arthroplasty and hip arthroplasty, the two most common surgeries, were associated with in-hospital transfusion frequencies of 2.8% and 4.5%, respectively. RBC transfusion occurred in 25.0% of hip fracture surgeries, accounting for the greatest total number of RBC units transfused in our cohort (38.0% of all transfused RBC units). Platelet and plasma transfusions were uncommon.

Conclusion
Orthopaedic surgeries were associated with variable rates of transfusion. The rate of RBC transfusion is highly dependent on the surgery type. Identifying surgeries with the highest transfusion rates, and further evaluation of factors that contribute to transfusion in identified at-risk populations, can serve to inform perioperative planning and blood bank requirements, and facilitate pre-emptive transfusion mitigation strategies.

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Introduction
Allogeneic blood transfusion is a limited and costly resource.[1] Approximately 700,000 red blood cell (RBC) units are administered in Canada each year, and while the transfusion rate has stabilized in recent years, the eligible donor pool is declining.[2] The global cost of each RBC unit is estimated to be $700 CAD, with the cost of maintaining the Canadian blood supply approximating $1 billion CAD, annually.[3,4] While transfusions can be lifesaving, they are associated with allergic and nonallergic transfusion reactions, infection, and immune dysregulation.[5-9] Transfusions are also associated with prolonged postoperative length of stay and increased morbidity, reflecting underlying medical comorbidities and surgical complexity in the patients who require transfusion.[7,10-12]

Orthopaedic surgeries are high-volume, complex surgeries that are increasing in

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frequency along with the ageing of the population.[13-17] The two most commonly performed orthopaedic surgeries, hip and knee arthroplasty, are performed approximately 62,000 and 75,000 times annually in Canada.[18] Published data describing transfusion practices in orthopaedic surgery are variable. Over the past two decades, the reported frequency of RBC transfusion ranged from 19% to 57% in elective hip and knee arthroplasty,[19-26] 54% to 83% in revision hip arthroplasties,[27,28] and 42% to 56% in hip fracture surgeries.[29,30] Previously published studies do not reflect present-day efforts to minimize perioperative transfusion, such as preoperative anaemia correction, modification of surgical techniques, changes to transfusion thresholds, or the use of pharmacological therapies to minimize bleeding, such as tranexamic acid.[7,31-34] The objective of our study was to describe contemporary transfusion practices in orthopaedic surgery to inform patient consent discussions, perioperative planning, and blood bank utilization.

Methods

Study design and data sources. We conducted a multicentre retrospective cohort study of all adult patients (≥ 18 years of age) who underwent orthopaedic surgery at two hospitals in Winnipeg, Manitoba and two hospitals in Ottawa, Ontario between 1 January 2014 and 31 December 2016. These are tertiary care centres that provide health services to approximately 2 million people. We obtained research ethics board approval for this study at both the University of Manitoba and University of Ottawa. Our review was conducted in accordance with the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) reporting guidelines.

We obtained patient demographic, clinical, and hospitalization data from the Discharge Abstract Database (DAD), a national database that captures patient hospitalizations.[35] The DAD at each hospital undergoes a continual process of data quality assurance and data validation, and uses standard International Classification of Diseases (ICD) coding for diagnoses and comorbidities and Canadian Classification of Health Interventions (CCI) coding for surgical procedures.[36] Manitoba transfusion data was obtained from a provincial transfusion database (TraceLine), which is dually governed by Diagnostic Services Manitoba (DSM) and Canadian Blood Services (CBS). Supplementary laboratory data in Manitoba were obtained from the hospital Laboratory Information System (LIS). Ontario transfusion and laboratory data were obtained from the Ottawa Hospital Data Warehouse, a repository of clinical and health administrative data that is routinely validated to ensure accuracy.[37]

Study population. We evaluated all adult patients admitted to hospital for nonarthroscopic joint surgeries, amputations, and fracture surgeries. We initially included all patients admitted to hospital with a CCI code reflecting an orthopaedic surgery. By exclusively evaluating inpatient surgeries, we excluded day surgeries at low risk for RBC transfusion. We excluded patients who underwent more than one surgery during a hospitalization as multiple surgeries could confound procedure-specific transfusion rates. If a patient was readmitted to hospital during the study period, we evaluated only their initial admission. Arthroscopic surgeries, hardware removal procedures, and reductions without fixation were excluded, in order to identify and evaluate a cohort of orthopaedic surgeries at higher risk for RBC transfusion. Spine surgeries were excluded as they were considered to represent a unique and heterogeneous surgical population operated on by both orthopaedic and nonorthopaedic specialists. Low frequency surgeries, defined as those occurring less than five times over the study period, were also excluded. In collaboration with orthopaedic surgery stakeholders, clinically relevant surgical subgroups were generated based on the CCI procedure codes and ICD-10 diagnosis codes (Figure 1 and Supplementary Table i).

Study variables. From the DAD we captured patient demographic details including age, sex, and baseline comorbidities. The Charlson Comorbidity Index was used to represent comorbidity burden.[38,39] Surgical details were obtained using standardized CCI procedure codes.[40] Surgical information included surgery type, surgery date/time, and surgical urgency (e.g. elective, urgent/emergent). Hospital admission details included hospital site, length of stay, admission to the intensive care unit (ICU), and in-hospital mortality. We included all RBC, platelet, and plasma transfusions administered during the index hospital admission.

Outcomes. For each surgical subgroup we characterized the proportion of patients who received RBC transfusions, the mean/median number of RBC units transfused, and the timing of transfusion relative to the surgery. We summarized the distribution of RBC transfusions by describing the orthopaedic surgeries with the highest frequency of transfusion, as well as those with the highest number of RBC units transfused, annually. This approach identified common surgeries where a high proportion of patients were transfused a smaller number of RBC units, and lower frequency surgeries where relatively fewer patients received a larger total number of RBC units. We also characterized the proportion of patients who received platelet and plasma transfusions, and the volume of platelets and plasma transfused. Additional clinical outcomes included hospital length of stay, ICU admission, and in-hospital mortality.

Statistical analysis. Continuous variables were summarized as means and standard deviations (SDs), and medians and interquartile ranges, where appropriate. Categorical variables were summarized as proportions. All analyses were conducted using Statistical Analysis Software (SAS version 9.4 for Windows; SAS Institute, USA).

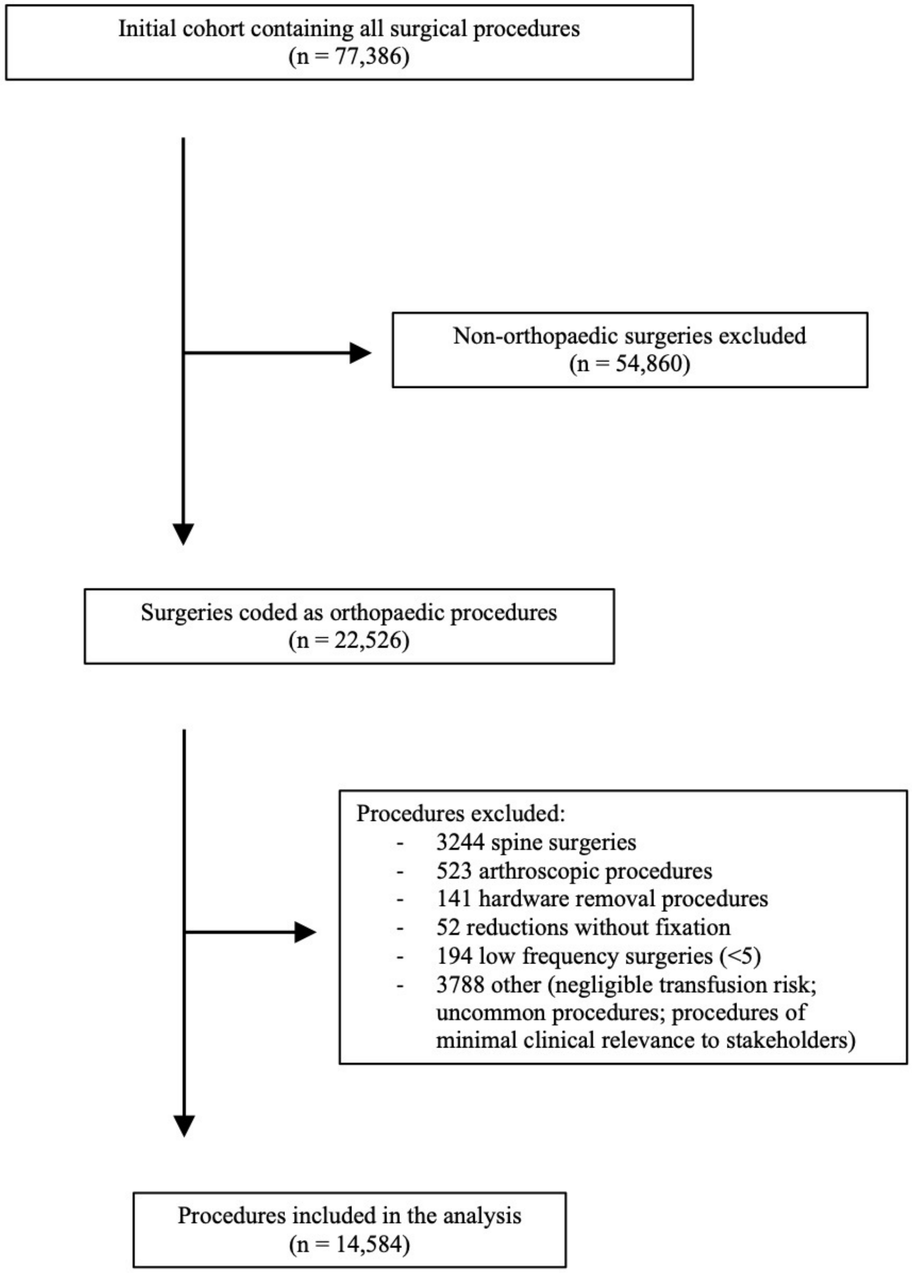

Fig. 1

Flowchart for the identification of orthopaedic procedures for analysis.

Results

Surgical population. In four centres, we identified 22,526 orthopaedic surgeries during the two-year study interval, and included 14,584 patients undergoing nonarthroscopic joint surgeries, amputations, and fracture surgeries (Figure 1). The surgical volume was distributed evenly between Winnipeg (n = 7,719; 52.9%) and Ottawa (n = 6,865; 47.1%) (Supplementary Table ii).

Baseline characteristics. The mean age in our cohort was 64.3 years (SD 13.6), which varied substantially according to the specific surgery performed (Table I). Females represented 56.0% of the population. Mean comorbidity scores ranged from 0.0 (SD 0.2) among patients undergoing distal radioulnar open reduction and internal fixation (ORIF) to 5.3 (SD 3.4) among patients undergoing femur ORIF. Nearly half (42.3%) of all surgeries were urgent/emergent. The most frequent surgeries were knee arthroplasty (n = 3,613; 24.8%), hip arthroplasty (n = 3,594; 24.6%), and hip fracture surgery (n = 2,540; 17.4%).

Description of transfusions in orthopaedic surgery. Overall, 10.3% (n = 1,496) of patients received RBC transfusion during their hospital admission (Table I). The proportion of individuals transfused varied widely

Table I. Patient demographics and red blood cell transfusion outcomes.

Surgery	Surgeries, n	Mean age, yrs (SD)	Sex, % male	Mean CCI (SD)	Surgical urgency,* % emergent	Proportion receiving RBCs, % transfused	Mean RBC units transfused, n (SD)†
Upper limb arthroplasty	766	68.3 (11.5)	38.5	0.5 (0.9)	10.1	3.9	2.1 (1.5)
Total shoulder arthroplasty	604	70.1 (9.7)	40.1	0.5 (0.9)	4.1	4.5	2.0 (1.5)
Shoulder hemiarthroplasty	60	64.6 (11.7)	41.7	0.4 (0.6)	28.3	0.0	-
Shoulder arthroplasty revision	13	63.7 (11.4)	38.5	0.2 (0.4)	7.7	0.0	-
Elbow arthroplasty	84	58.8 (16.3)	23.8	0.5 (0.8)	40.5	3.6	2.7 (1.2)
Elbow arthroplasty revision	5	55.8 (16.3)	60.0	1.0 (1.0)	0.0	0.0	-
Upper limb fracture fixation	1,175	51.0 (18.9)	45.6	0.4 (1.2)	73.5	5.1	3.1 (2.7)
Clavicle fracture	114	40.5 (16.3)	62.3	0.1 (0.4)	54.4	1.8	3.5 (0.7)
Shoulder ORIF	110	58.4 (15.5)	33.6	0.2 (0.6)	55.5	12.7	3.1 (2.5)
Humerus ORIF	332	54.7 (18.3)	41.3	0.8 (2.0)	65.7	8.7	3.4 (3.4)
Elbow ORIF	168	52.5 (20.5)	38.7	0.3 (0.8)	85.2	3.6	2.0 (0.6)
Radius/ulna ORIF	358	48.8 (19.0)	49.2	0.2 (0.5)	81.6	2.2	2.6 (1.2)
Distal radioulnar ORIF	33	42.2 (17.1)	63.6	0.0 (0.2)	87.9	3.0	4.0
Wrist ORIF	60	50.5 (17.4)	48.3	0.1 (0.4)	85.0	0.0	-
Pelvis ORIF	99	48.3 (18.6)	71.7	0.1 (0.5)	91.9	31.3	4.1 (3.5)
Hip arthroplasty	3,594	64.1 (13.0)	49.0	0.3 (1.0)	6.4	8.1	3.2 (2.6)
Total hip arthroplasty	3,079	63.3 (12.8)	49.7	0.3 (1.0)	2.0	4.5	3.0 (2.4)
Hip arthroplasty revision	515	69.0 (13.6)	44.7	0.4 (1.0)	32.4	29.7	3.4 (2.7)
Hip fracture surgery‡	2,540	78.9 (13.8)	32.3	0.8 (1.4)	98.4	25.0	3.1 (2.5)
Hip ORIF	1,447	77.8(15.7)	32.5	0.8 (1.4)	98.3	31.0	3.2 (2.7)
Total hip arthroplasty (fracture)	288	75.5 (12.7)	35.1	0.7 (1.3)	97.6	14.2	3.1 (2.1)
Hip hemiarthroplasty (fracture)	805	82.1 (9.2)	30.9	0.9 (1.4)	98.8	18.3	2.7 (1.9)
Femur ORIF‡	95	64.8 (14.3)	43.2	5.3 (3.4)	71.6	25.3	4.8 (2.4)
Knee arthroplasty	3,613	66.7 (10.2)	39.0	0.4 (0.7)	2.8	3.3	3.3 (4.4)
Total knee arthroplasty	3,140	66.8 (10.2)	38.7	0.4 (0.7)	2.3	2.8	2.9 (4.0)
Knee arthroplasty revision	473	65.8 (10.1)	40.8	0.3 (0.7)	6.1	6.3	5.4 (6.7)
Patella ORIF	85	52.3 (20.4)	38.8	0.5 (1.4)	83.5	3.5	3.0 (1.0)
Tibia/fibula ORIF	416	45.7 (16.6)	52.4	0.1 (0.5)	88.9	5.1	3.1 (2.0)
Ankle arthroplasty	24	68.1 (7.4)	45.8	0.2 (0.5)	4.2	0.0	-
Ankle and foot ORIF	1,388	48.2 (18.4)	50.3	0.2 (0.7)	88.8	1.5	3.9 (3.0)
Amputation	789	65.0 (14.9)	65.8	2.0 (1.7)	71.5	33.1	4.4 (4.2)
Forearm amputation	7	64.6 (19.4)	71.4	0.9 (1.5)	71.4	14.3	1.0
Above-knee amputation	186	71.7 (15.7)	52.7	2.0 (2.2)	81.2	43.6	4.2 (3.8)
Below-knee amputation	364	62.1 (13.2)	71.4	1.8 (1.6)	62.6	38.5	4.6 (4.6)
Midfoot and toe amputation	232	64.3 (15.1)	67.2	2.4 (1.4)	77.6	16.8	4.6 (3.3)
Total	14,584	64.3 (13.6)	44.0	0.5 (1.0)	42.3	10.3	3.3 (3.1)

*Urgency status: elective vs emergent.
†In those transfused.
‡Hip fractures were defined as trochanteric or more proximal fractures, while femur fractures were defined as subtrochanteric or more distal fractures.
CCI, Canadian Classification of Health Interventions; ORIF, open reduction and internal fixation; RBC, red blood cell; SD, standard deviation.

among surgical subgroups. Patients undergoing surgeries such as shoulder hemiarthroplasty, wrist ORIF, and ankle arthroplasty rarely required RBC transfusion, whereas a higher proportion of patients were transfused during hip fracture surgery (25%), femur ORIF (25.3%), pelvis ORIF (31.3%), and amputation (33.1%). Primary knee arthroplasty and hip arthroplasty, the two most common surgeries, were associated with a transfusion rate of 2.8% and 4.5%, respectively. In comparison, the transfusion rates for revision knee arthroplasty and revision hip arthroplasty were 6.3% and 29.7%, respectively.

Of those transfused, patients received a mean of 3.3 units (SD 3.1) of RBCs during their hospital admission. The volume transfused was variable and depended on surgical subgroups (Table I, Supplementary Table iii). Patients undergoing upper arm arthroplasty surgery received the lowest volume of RBCs (2.1 units (SD 1.5)), whereas amputations (4.4 units (SD 4.2)) and femur ORIF (4.8 units (SD 2.4)) were associated with the largest volume of RBCs transfused. The surgeries with the highest annual total number of RBC transfusions were hip fracture surgeries (2,540 surgeries; 1,969 units), amputations (789 surgeries; 1,149 units), and elective hip arthroplasties (3,594 surgeries; 932 units) (Figure 2). Platelet (0.4% of surgeries) and plasma (0.5% of surgeries) transfusions were rare (Supplementary Table iii).

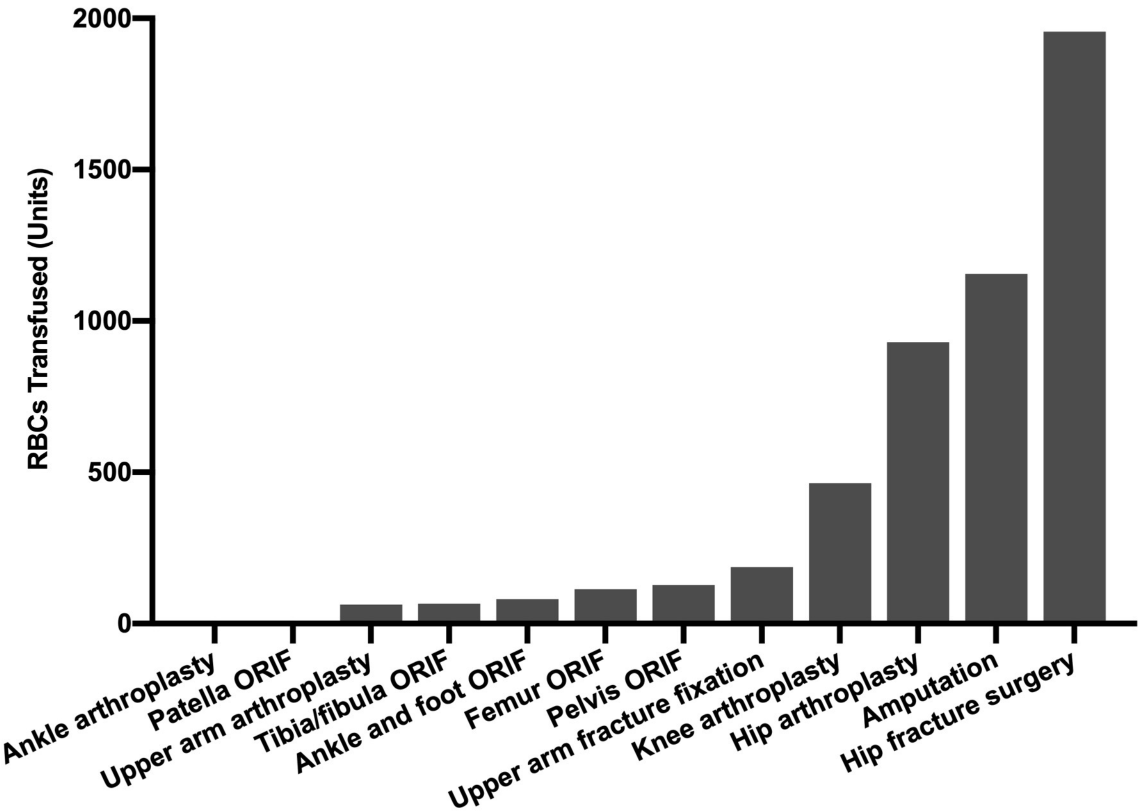

Fig. 2

Total number of red blood cell (RBC) units transfused, reflecting the surgery-specific transfusion burden over the study period. The transfusion burden was determined based on surgical frequency and the proportion of patients who received an RBC transfusion. ORIF, open reduction and internal fixation.

Surgery-specific transfusion rates in Winnipeg and Ottawa were generally similar (Supplementary Table ii). The proportion of patients receiving RBC transfusion was higher among patients undergoing urgent/emergent surgery (18.2%) compared to elective surgery (4.4%).

The median time from hospital admission to surgery was 13 hours (IQR 10 to 37). Most (n = 3,528; 68.5%) RBC transfusions occurred postoperatively, with 17.2% of the transfusions administered preoperatively, and 14.3% of transfusions administered intraoperatively (Figure 3). The majority (76.4%) of RBC transfusions occurred within the first seven days of hospital admission.

Non-transfusion clinical outcomes are itemized in Supplementary Table iv. The median length of hospital stay for all patients was 4.5 days (IQR 3 to 8). Patients undergoing ankle and upper arm arthroplasties had the shortest hospital stay of two days (IQR 2 to 3.5) and two days (IQR 1 to 4), respectively. Patients undergoing pelvis ORIF or amputation surgeries had the longest hospital stay, at a median of 11 days (IQR 6 to 19) and 12 days (IQR 6 to 23), respectively. ICU admission was uncommon in this cohort (< 15% for any surgical subgroup), with the exception of pelvis ORIF, where 21.2% of patients were admitted to an ICU. In-hospital mortality was generally low (1.2%), although it was notably higher for individuals requiring above-knee amputation (10.8%).

Discussion

In this large multicentre cohort of patients undergoing orthopaedic surgery, approximately 10% of patients received RBC transfusion. The incidence of RBC transfusion varied widely according to the specific surgery performed. While hip fracture surgeries represented less than 20% of all surgeries, nearly half of all transfused RBC units were administered to patients undergoing this surgery. The majority of transfusions occurred postoperatively, and within the first seven days of hospital admission. Platelet and plasma transfusions were uncommon.

The transfusion rates identified in our study are considerably lower than reported previously.[19-30] In our study, 10.3% of all patients received RBC transfusion, and primary hip and knee arthroplasty were associated with transfusion rates of 2.8% and 5.4%, respectively. This contrasts with previously reported transfusion rates that range from 19% for elective hip and knee arthroplasty in the USA to 57% for various orthopaedic procedures in Italy.[19,20] The lower transfusion rates observed in our cohort likely reflect the implementation of strategies to mitigate perioperative transfusion including preoperative anaemia correction, advances in surgical technique, changes to transfusion thresholds, and the use of tranexamic acid.[7,20,22,28,31,34,41] Using

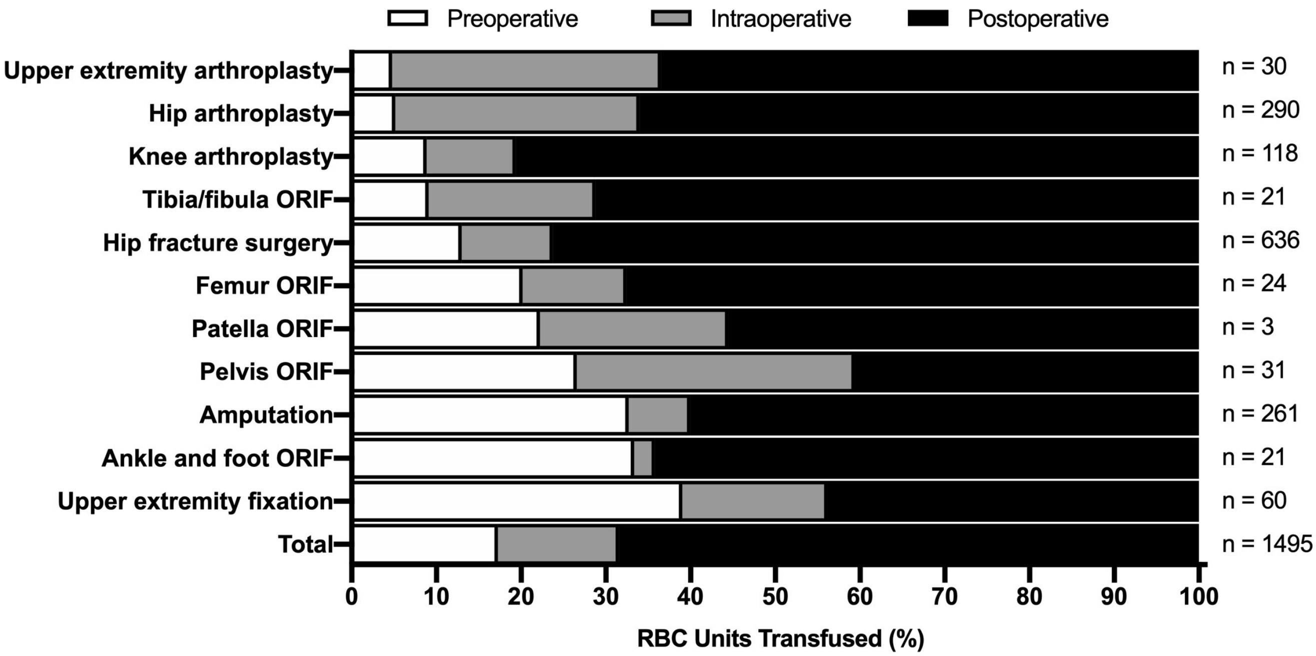

Fig. 3

Timing of red blood cell (RBC) transfusion in relation to the surgery. RBC transfusions in patients undergoing orthopaedic surgeries were classified based on their timing relative to the surgery: preoperative (white), intraoperative (grey), and postoperative (black). Numbers to the right of the figure are the number of surgeries each row represents. ORIF, open reduction and internal fixation.

contemporary data, we have reported modern informative estimates of surgery-specific transfusion rates (e.g. hip fracture surgery compared to hip arthroplasty), and of increased transfusion risk for urgent/emergent fracture-related surgeries.[20,22]

The majority (68.5%) of RBC transfusions occurred in the postoperative period, within the first seven days of hospital admission. As such, the timing of RBC transfusion may reflect surgical and early postoperative clinical factors rather than issues related to prolonged hospital admission or late surgical complications. Variability in the frequency of RBC transfusion among surgical subgroups may reflect both surgical differences and differences in baseline patient characteristics such as patient age, sex, comorbidities, anaemia severity, or bleeding risk factors.[42] The frequency of transfusion could likewise be impacted by cultural differences in RBC transfusion threshold decisions depending on the clinical care unit (e.g. operating room vs ICU), or by the variable use of antifibrinolytic agents.[43,44]

Patients undergoing femur ORIF, pelvis ORIF, or amputation were frequently transfused with larger RBC volumes. This observation may be explained by the mechanism of injury in patients with femur or pelvis fractures; these fractures are more likely to be the result of high-energy trauma and patients may have additional injuries. Those undergoing amputation are more likely to have additional comorbidities, chronic diseases, or predisposition to anaemia (Table I).[45,46]

Hip fracture surgery was associated with the highest annual volume of RBC transfusions (1,969 units), reflective of both the frequency of the surgery and the RBC transfusion rate (Figure 2). This may reflect the urgent nature of the surgery, which provides less opportunity for preoperative anaemia correction, the vascular nature of bone, and the inability to perform these surgeries under tourniquet. Patients undergoing hip fracture surgery were also older and predominantly female, both of which have previously been identified as risk factors for transfusion in orthopaedic surgical patients.[19,20,23,24] Recognizing hip fracture surgery as a surgery associated with a higher transfusion burden highlights a population for targeted transfusion reduction interventions or research, for blood bank inventory management, and for surgical planning.

In the area of hip fracture surgery, the orthopaedic surgical procedure associated with the highest total number of RBC units transfused per year, there are evolving recommendations for transfusion thresholds, as well as strategies to minimize transfusion. Several clinical practice guidelines recommend a transfusion threshold of < 80 g/l for patients undergoing orthopaedic surgery, and specifically in patients undergoing hip fracture surgery.[11,47-49] The preoperative measurement of haemoglobin three to four weeks before surgery has also been recommended to permit optimization prior to surgery.[7,50] This can be challenging to accomplish in the urgent setting, and should not delay surgery. There have been several studies evaluating the use of tranexamic acid in hip fracture surgery, which suggest that tranexamic acid decreases blood loss and transfusion requirements.[51] However, at this time, no standardized regimen for tranexamic acid administration in hip fracture surgery has been adopted.[51] This is in contrast to the use of tranexamic acid in total hip and knee arthroplasty, where clinical practice guidelines already exist.[52]

The strengths of this study include the large consecutive cohort from four hospitals in two Canadian cities, which increases the generalizability of our findings to other Canadian orthopaedic surgery centres. Contrary to previously published estimates of transfusion frequency, the transfusion frequency observed in our study likely reflects modern perioperative blood management and transfusion practices used at the participating sites. A potential limitation of our study is the initial use of CCI codes to determine the specific surgeries performed, as these codes do not always match the clinical description of the surgery performed. To mitigate this, we interpreted the CCI codes in the context of the ICD-10 diagnosis codes. Expert input from orthopaedic stakeholders helped ensure that defined surgical groups reflected the surgeries performed. An additional limitation was that information about preoperative exposure to anticoagulants, anti-platelet agents, tranexamic acid, or iron supplementation was not available in our dataset.

RBC transfusion practices in orthopaedic surgery vary widely according to the specific surgery performed. The transfusion rates identified are lower than previously reported; contemporary estimates of transfusion rates will help inform perioperative planning and blood banking requirements. There remain research gaps in the evaluation of approaches to minimize transfusion in orthopaedic surgery, particularly in hip fracture surgery.

Take home message

- Perioperative transfusion rates in orthopaedic surgery vary widely depending on the specific type of surgery performed.

Supplementary material

Canadian Classification of Health Interventions and ICD-10 codes used to create subgroups for analysis; location-specific transfusion outcomes; red blood cell, platelet, and plasma transfusion outcomes; and non-transfusion clinical outcomes.

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