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Evaluation of Transfusion Practices in Noncardiac Surgeries at High Risk for Red Blood Cell Transfusion: A Retrospective Cohort Study

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ABSTRACT

Perioperative bleeding is a major indication for red blood cell (RBC) transfusion, yet transfusion data in many major noncardiac surgeries are lacking and do not reflect recent blood conservation efforts. We aim to describe transfusion practices in noncardiac surgeries at high risk for RBC transfusion. We completed a retrospective cohort study to evaluate adult patients undergoing major noncardiac surgery at 5 Canadian hospitals between January 2014 and December 2016. We used Canadian Classification of Health Interventions procedure codes within the Discharge Abstract Database, which we linked to transfusion and laboratory databases. We studied all patients undergoing a major noncardiac surgery at ≥5% risk of perioperative RBC transfusion. For each surgery, we characterized the percentage of patients exposed to an RBC transfusion, the mean/median number of RBC units transfused, and platelet and plasma exposure. We identified 85 noncardiac surgeries with an RBC transfusion rate ≥5%, representing 25,607 patient admissions. The baseline RBC transfusion rate was 16%, ranging from 5% to 49% among individual surgeries. Of those transfused, the median (Q1, Q3) number of RBCs transfused was 2 U (1, 3 U); 39% received 1 U RBC, 36% received 2 U RBC, and 8% were transfused ≥5 U RBC. Platelet and plasma transfusions were overall low. In the era of blood conservation, we described transfusion practices in major noncardiac surgeries at high risk for RBC transfusion, which has implications for patient consent, preoperative surgical planning, and blood bank inventory management.

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Approximately 700,000 red blood cell (RBC) transfusions are administered annually in Canada, with an estimated cost of $600 per unit and approximately $1 billion in Canadian health care expenditure each year [1-3]. Although transfusions can be life-saving, they are not without harm [4]. Transfusions are associated with both allergic and nonallergic transfusion reactions, infection, immune dysregulation, prolonged postoperative length of stay, and increased morbidity [5-10].

Perioperative bleeding is a major indication for allogeneic RBC transfusion and is the third most common indication for transfusion in US hospital inpatients [11,12]. Approximately 50% of patients undergoing major cardiac and orthopedic surgery receive a perioperative transfusion [13-15]. Data are lacking in other major noncardiac surgeries and do not reflect recent efforts to minimize perioperative transfusion [7,16-19]. The objective of our study is to describe transfusion practices in noncardiac surgeries at high risk for RBC transfusion to inform patient consent discussions, preoperative planning, and blood bank utilization by health care practitioners and health system administrators.

1. Materials and Methods

1.1. Study Design

We completed a retrospective cohort study to evaluate all patients (≥18 years of age) undergoing noncardiac surgery at 3 hospitals in Winnipeg, Manitoba (Health Sciences Centre, St. Boniface General Hospital, and Concordia Hospital), and 2 hospitals in Ottawa, Ontario (Ottawa Hospital, Civic and General Campuses), between January 1, 2014 and December 31, 2016. These are tertiary care centers that provide health service to approximately 2 million people.

1.2. Data Sources

We obtained patient demographics and clinical and administrative hospitalization data from the Discharge Abstract Database (DAD), a national database which captures patient hospitalizations. The DAD at each hospital undergoes a continual process of data quality assurance and data validation, and uses standard International Classification of Diseases coding for diagnoses and comorbidities and Canadian Classification of Health Interventions (CCI) coding for surgical procedures [20]. Manitoba transfusion data were obtained from a provincial transfusion database (TraceLine) dually governed by Diagnostic Services Manitoba and Canadian Blood Services. Supplementary laboratory data in Manitoba were obtained from the hospital Laboratory Information System. Ontario transfusion and laboratory data were obtained from the Ottawa Hospital Data Warehouse, a repository of clinical and health administrative data that are routinely validated to ensure accuracy.

1.3. Study Population

We evaluated all patients undergoing a major noncardiac surgery at high risk of perioperative RBC transfusion. *High risk* of RBC transfusion was a priori defined as 5% or greater. This transfusion threshold was chosen because clinicians and patient partners identified that a 1 in 20 chance of transfusion was both substantive and allowed inclusion of a broad patient population. We included all patients with an inpatient visit and a CCI code. To focus on a surgical population at high risk for RBC transfusion, we removed lower-risk day surgeries by exclusively evaluating inpatient surgeries. We isolated surgeries to those conducted in the main operating room to remove low-risk procedures performed in the emergency department, radiology suite, and hospital ward. We excluded all patients with >1 surgery during their hospitalization, as this could confound the surgery-specific transfusion rates. If a patient was readmitted for another surgery during the study period (2014-2016), we evaluated only their initial hospital admission.

We stratified the CCI codes by surgical approach, which allowed distinction between open and minimally invasive surgeries, as this has clinically significant bleeding implications [21,22]. Using the letters in the sixth and seventh positions of the CCI codes, letters *AA* to *KS* were assigned as "minimally invasive," whereas letters *KZ* to *XY* were assigned as "open." As the granularity of CCI codes can make the clinical interpretation challenging (n = 2863 unique codes), we renamed and reclassified the CCI codes to reflect clinically relevant surgeries using both the Canadian Classification of Health Interventions alphabetical index [23,24] and the Winnipeg Regional Health Authority Surgical Information Management System Procedure Catalog [25]. A list of the CCI codes along with their corresponding surgical descriptions is included in Appendix A. We further refined the surgical population by removing all uncommon procedures (absolute number <30 over the 3-year period), low-risk procedures (transfusion rate <5%), procedures outside of our surgical scope (cardiac, obstetrics), and procedures not associated with bleeding (ie, intubation, biopsies) (Fig 1).

1.4. Study Variables

We obtained patient demographics including age, sex, baseline comorbidities, admission diagnosis, and preoperative hemoglobin. Baseline comorbidities were evaluated using the Charlson comorbidity index [26]. For preoperative hemoglobin, we obtained the value drawn closest to the start of surgery, within the preceding 4 weeks. *Preoperative anemia* was defined as a hemoglobin value less than 140 g/L in men and 130 g/L in women [27]. Surgical information, including surgery name, date/time, and urgency (eg, elective, urgent/emergent), was obtained from the DAD using standardized CCI procedure codes [23,24]. To evaluate transfusions related to perioperative bleeding, we included all transfusions from the start of surgery to 7 days postoperatively or hospital discharge, whichever occurred first.

1.5. Outcomes

For each surgical domain and individual surgery, we characterized the percentage of patients exposed to RBC transfusion and the mean/median number of RBC units transfused. We summarized the distribution of RBC

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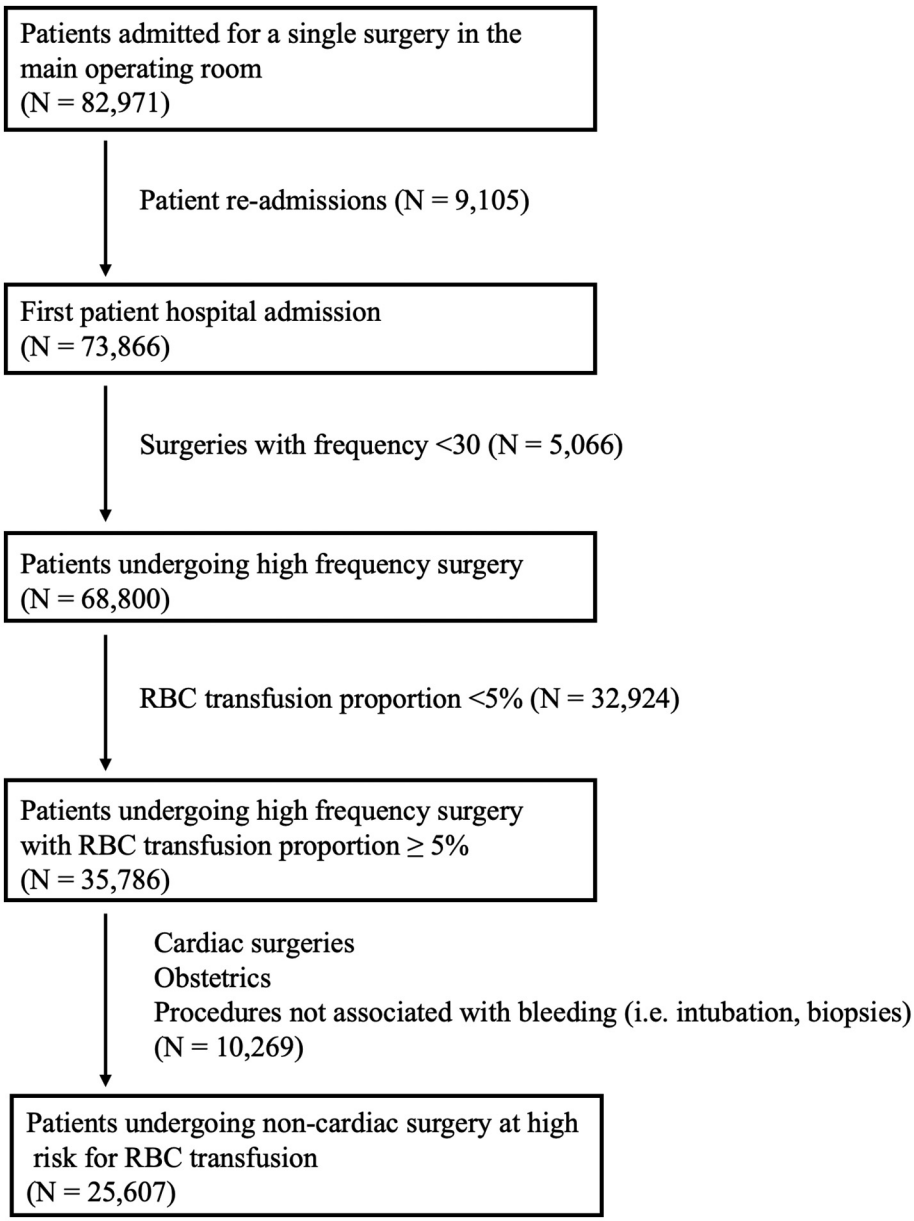

Fig 1. Flow diagram depicting the derivation of our surgical cohort.

transfusions by describing the noncardiac surgeries with the highest risk of transfusion, as well as those with the highest annual number of RBC units transfused (ie, transfusion burden). This identifies common surgeries where a high percentage of patients are transfused a low number of RBC units and lower-frequency surgeries where patients receive larger numbers of RBC units. For each individual surgery, we evaluated the percentage of patients requiring ≥5 U RBC and the timing of RBC transfusion in relation to the surgery. Lastly, we evaluated the percentage of patients exposed to platelets and plasma.

1.6. Subgroup Analyses

A priori subgroup analyses included the study of differences in RBC transfusion according to surgical urgency (elective vs urgent/emergent) and surgical approach (open vs minimally invasive).

1.7. Analysis

Baseline characteristics were summarized as means (standard deviation [SD]), medians (interquartile range), or frequency (percentage), as appropriate. We analyzed group differences in categorical or continuous data using χ^2 and *t* tests, as appropriate. *P* values less than .5 were considered significant. Sample size calculations were not performed because the primary intent of this analysis was descriptive and the cohort was derived by convenience sampling. Missing data were evaluated and summarized. We conducted all analyses using SAS/STAT software (SAS version 9.4 for Windows; SAS Institute Inc, Cary, NC).

2. Results

2.1. Baseline Characteristics

In our 5 centers, we captured 82,971 patient admissions with a single surgery performed in hospital operating rooms and 85 noncardiac surgeries with an RBC transfusion rate ≥5%, which represented 25,607 patient admissions (Fig 1). The surgical distribution between cities was comparable. Most surgeries were elective (n = 16,383; 64%) and performed using an open surgical approach (69/85; 81%). The mean patient age was 63 years (SD 17 years), and 55% were female. Preoperative

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Table 1
Baseline demographics categorized by surgical domain

Surgical domain	Surgical volume (# surgeries/y)	Urgency (% elective)	Mean age (SD)	Sex (% female)	Mean Charlson CI (SD)	Mean preop Hb (g/L) (SD)	% Transfused	Mean # RBC units[a] (SD)	RBC burden (# U/y)
General surgery	4907	57	62.1 (16.3)	48	2.1 (2.8)	121 (23)	17.5	2.5 (2.7)	719
Gynecology	3792	96	52.3 (13.2)	100	1.2 (2.1)	125 (18)	9.5	2.4 (1.7)	285
Neurosurgery	296	61	56.7 (12.1)	71.0	0.9 (1.0)	133 (17)	11.6	2.2 (1.6)	25
Orthopedic surgery	8515	47	70.0 (17.1)	56.7	0.6 (1.5)	121 (20)	17.2	1.9 (1.2)	929
Otolaryngology	187	97	61.2 (13.9)	44.4	3.2 (3.0)	130 (15)	8.1	2.0 (0.8)	10
Plastic surgery	416	63	56.5 (16.8)	44.7	1.2 (1.8)	118 (24)	9.4	2.2 (1.1)	28
Spine surgery	2233	66	56.6 (15.3)	43.1	0.3 (1.3)	133 (19)	16.6	2.9 (2.2)	352
Thoracic surgery	736	73	59.5 (16.5)	43.2	2.1 (2.6)	124 (22)	17.3	2.4 (2.6)	103
Urology	1775	81	63.2 (14.3)	25.4	2.2 (1.8)	121 (22)	16.2	2.8 (2.5)	272
Vascular surgery	2750	69	70.1 (11.9)	30.3	1.1 (1.2)	128 (21)	22.2	3.1 (3.8)	636

CI, comorbidity index; Hb, hemoglobin; Preop, preoperative; U, units; Y, year; SD, standard deviation.
[a] Mean number of RBC transfusions in those patients who received a RBC transfusion.

hemoglobin values were available in 67% of the cohort, with more complete capture among patients undergoing urgent/emergent surgeries (95%). Other study variables had near complete (>99%) capture. Baseline demographics classified by surgical domain and individual surgery type are included in Table 1 and Appendix B, respectively.

2.2. Description of RBC Transfusion Among the Individual Surgeries

In our surgical cohort, the baseline RBC transfusion rate was 16% and ranged from 5% to 49% among individual surgeries. Of those transfused, the median (Q1, Q3) number of RBCs transfused was 2 U (1, 3 U); 39% received 1 U RBC, 36% received 2 U RBC, and 8% were transfused ≥5 U RBC. The 10 surgeries with the highest RBC transfusion risks were open cystectomy (49%), open abdominal aortic repair (46%), open splenectomy (46%), spinal fusion with vertebrectomy (38%), open abdominal aortic bypass (38%), open gastroplasty (36%), femur open reduction internal fixation (35%), above-knee amputation (32%), open gastrectomy (30%), and endoscopic femur fixation (30%) (Table 2, Fig 2, Appendix C). The surgeries that led to the largest annual numbers of RBC units transfused included femur open reduction internal fixation (558 surgeries; 1094 U RBC), open hip arthroplasty (1577 surgeries; 896 U RBC), hysterectomy (1127 surgeries; 773 U RBC), abdominal aortic repair (112 surgeries; 720 U RBC), and spinal fusion (531 surgeries; 677 U RBC).

Of those who received a RBC transfusion, 27% were transfused intraoperatively, 60% were transfused postoperatively, and 13% were transfused both intraoperatively and postoperatively. Overall, 40% of the RBC units were transfused intraoperatively, and 60% were transfused postoperatively. Postoperative transfusions were administered a median of 50 hours (28, 77 hours) after surgery completion. Platelet and plasma transfusions were overall low, with 4% (3/85) and 12% (10/85) of surgeries associated with a platelet and plasma transfusion rate ≥5%, respectively (Appendix C).

2.3. Subgroup Analyses

Compared to elective surgical patients, those admitted for an urgent/emergent surgery were more likely to have preoperative anemia (hemoglobin 118g/L [95% confidence interval 118-119 g/L] vs 130 g/L [95% confidence interval 129-130 g/L]) and were more likely to receive an RBC transfusion (26% vs 11%; $P < .001$). RBC transfusion was higher among patients undergoing open surgeries compared to minimally invasive surgeries (17% vs 11%; $P < .001$).

3. Discussion

In the era of blood conservation initiatives, we have described transfusion practices in major noncardiac surgeries at high risk (≥5%) for RBC transfusion. We focused on both the percentage of patients transfused

Table 2
Surgery-specific transfusion outcomes

Surgery	# Surgeries/y	Mean age (SD)	Sex (% female)	Mean Charlson CI (SD)	Mean preop Hb (g/L) (SD)	% Transfused	Mean # U RBC[a] (SD)	Transfusion burden (# U RBC/y)
Surgeries with the highest percentage of patients transfused								
Open cystectomy	53	65.6 (11.5)	28	2.8 (2.6)	125.9 (18.3)	**49.1**	78.0 (3.1)	239
Open abdominal aortic repair	112	70.8 (8.6)	23	1.2 (1.1)	131.2 (21.9)	**46.3**	156.0 (4.6)	720
Open splenectomy	17	49.1 (17.5)	56	0.6 (1.5)	107.1 (26.4)	**46.0**	23.0 (4.8)	111
Spinal fusion with vertebrectomy	57	56.8 (13.6)	49	0.8 (2.1)	126.7 (20.7)	**38.4**	66.0 (3.5)	233
Open abdominal aortic bypass	63	65.8 (9.4)	30	1.0 (0.9)	135.6 (19.6)	**38.3**	72.0 (2.9)	210
Surgeries with the highest transfusion burden								
Femur open reduction internal fixation	558	74.5 (18.6)	69	0.9 (1.8)	115.1 (18.5)	34.8	583.0 (1.9)	**1094**
Open hip arthroplasty	1577	68.1 (14.4)	55	0.4 (1.2)	128.7 (17.7)	10.1	480.0 (1.9)	**896**
Open hysterectomy	1127	52.6 (12.8)	100	1.2 (2.1)	124.9 (18.2)	9.5	320.0 (2.4)	**773**
Open abdominal aortic repair	112	70.8 (8.6)	23	1.2 (1.1)	131.2 (21.9)	46.3	156.0 (4.6)	**720**
Spinal fusion	531	57 (15.4)	41	0.2 (1.0)	132.4 (19.1)	16.1	257.0 (2.6)	**677**

Includes the top 5 surgeries with the highest percentage of patients transfused RBCs, as well as the top 5 surgeries with the highest annual transfusion burden (# U RBC transfused per year).
[a] Mean number of RBC transfusions in those patients who received an RBC transfusion.

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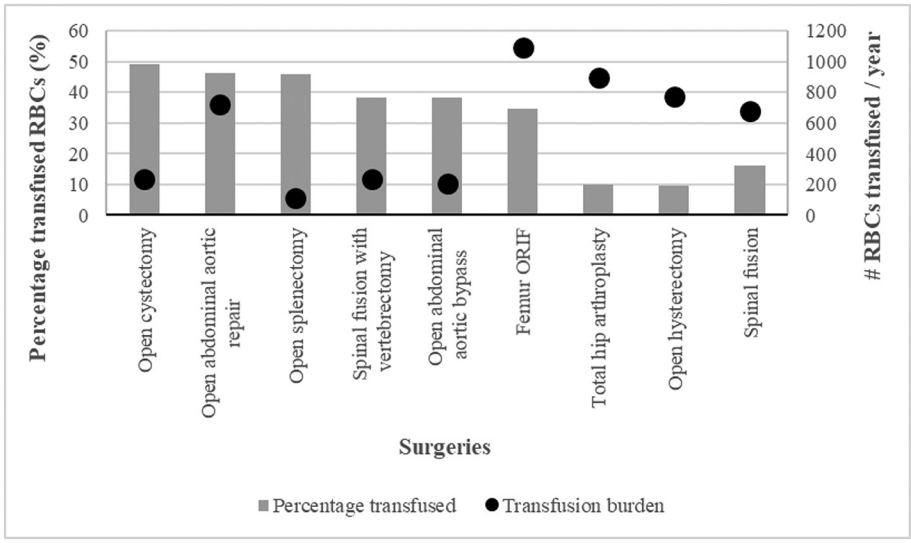

Fig 2. The top 5 surgeries ranked according to the percentage of patients transfused RBCs (%) and the number of RBC units transfused annually. This captures distinct surgical populations with differential impact on patients and the health care system.

RBCs as well as the number of RBCs transfused annually, as these measures have differing implications. Transfusion exposure is a patient prioritized outcome, which informs patient consent discussions and perioperative surgical planning. Transfusion burden considers both the percentage of patients transfused as well as surgical frequency, with systemic implications for the health care system and blood banking, as blood products are a costly but finite resource [1]. Except for open abdominal aortic artery repair, surgeries with a high percentage of RBC transfusion were distinct from those with the highest RBC transfusion burden, highlighting that both of these factors should be considered when evaluating perioperative transfusion practices.

Prior studies evaluating the frequency and distribution of real-world perioperative transfusion in noncardiac surgery are outdated and do not reflect recent efforts to mitigate blood transfusion, such as preoperative anemia correction, intraoperative cell salvage, variation in surgical technique, use of more restrictive transfusion thresholds, single-unit transfusion policies, and the increasing use of medications such as tranexamic acid [16-18,28-30]. Reflective of this, a patient blood management initiative in Ontario, Canada, demonstrated that the implementation of blood conservation efforts substantially reduces perioperative transfusion in select patient populations such as coronary artery bypass grafting, radical prostatectomy, and hip and knee arthroplasty [7]. Our study builds on these findings by providing a comprehensive and updated description of transfusion practices in noncardiac surgery in the era of blood conservation prioritization.

We preselected a higher-risk surgical population by limiting cohort inclusion to hospitalized patients undergoing a surgery with a transfusion rate ≥5%, a threshold felt to be meaningful to both patient partners and stakeholders. As expected, patients undergoing open surgery experienced increased RBC transfusion exposure, possibly related to the more invasive nature of the surgery, a preselection for higher-risk surgeries that may not be amenable to a minimally invasive approach, and the reduced venous blood loss in minimally invasive surgeries from venous collapse due to pneumoperitoneum-related pressure increases. Nonelective surgeries were also associated with increased RBC transfusion, likely due to the inability to correct preoperative anemia and increased illness acuity and severity.

Using a large multicenter cohort, we used high-fidelity datasets to reliably capture patient demographics, surgical information, and transfusion practices. We comprehensively described the transfusion practices in 85 noncardiac surgeries at high risk for RBC transfusion, involving approximately 25,000 patients. In doing so, we have addressed a knowledge gap by describing real-world transfusion practices in high-risk noncardiac surgery.

Our study describes transfusion practices in 5 Canadian centers; however, institutional differences in surgical practice and transfusion rates may impact generalizability, particularly in resource-limited settings where perioperative practice may vary. We described transfusion practices from 2014 to 2016, which may not reflect recent blood conservation initiatives and may therefore overestimate contemporary transfusion rates [19]. Surgical information was obtained from the DAD, and although standardized, the CCI codes do not directly reflect surgical descriptions in clinical practice. We tried to mitigate this potential limitation by involving surgical content experts and by using both administrative CCI code definitions as well as governmental descriptions to finalize our surgical cohort. The relationship between preoperative anemia and transfusion was difficult to ascertain because preoperative hemoglobin values were limited to 67% of our cohort, with reduced capture in elective surgeries. This likely relates to perioperative guidelines which discourage routine blood work prior to surgery [31]. Furthermore, it is possible that receipt of transfusion may not reflect true transfusion demand.

In the era of blood conservation, we have described the transfusion practices in major noncardiac surgeries at high risk for RBC transfusion. This has implications for patient consent discussions, preoperative surgical planning, and blood bank inventory management.

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Conflicts of interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tmrv.2020.08.001.

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