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Packed red blood cell transfusion after surgery: are we "overtranfusing" our patients?

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KEYWORDS:
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Abstract

BACKGROUND: Data on the hemoglobin (Hb) after transfusion, or the "target," which reflects the "dose" of blood given are not well studied. We sought to examine the incidence and causes of "over transfusion" of red blood cells after surgery.

METHODS: Data on blood utilization including Hb triggers and targets were obtained for patients undergoing colorectal, pancreas, or liver surgery between 2010 and 2013.

RESULTS: A total of 2,905 patients were identified, of which 895 (31%) were transfused (median age 64, interquartile range: 53 to 72; 51% men; median American Society of Anesthesiologists class 3, interquartile range: 3–3; 51% pancreatic, 14% hepatobiliary, 21% colorectal, and 14% other). Among these, 512 (57%) were overtransfused (final Hb target after transfusion ≥9.0 g/dL). Among patients who were overtransfused, 171 (33%) were transfused at too high an initial trigger (>8.0 g/dL), whereas 304 (59%) had an appropriate trigger but received ≥2 packed red blood cell (PRBC) units, suggesting an opportunity to have transfused fewer units. There was significant variation in overtransfusion among surgeons (range 0% to 80%, $P = .003$).

CONCLUSIONS: Excess use of blood transfusion is common and was due to PRBC utilization for too high a transfusion trigger, as well as too many units transfused.

Almost 14 million units of red cells were transfused in the United States in 2011.[1] Although blood transfusion can be lifesaving, and the risk of viral infectious transmission is lower than ever,[2] transfusion can result in febrile or allergic reactions and transfusion-related acute lung injury[3] and is associated with worsened oncologic[4] and perioperative outcomes, including increased mortality.[5–7] Several landmark randomized controlled trials have tested restrictive transfusion practices in various clinical scenarios, including intensive care, cardiac surgery,[8] joint replacement,[9] and

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gastrointestinal bleeding.[10] These studies have found that maintaining hemoglobin (Hb) levels between 7.0 and 9.0 g/dL resulted in equivalent or improved outcomes compared with more liberal transfusion practice. These results and increased focus on the costs of transfusion[11] have led to attempts to reduce red cell transfusion overuse.

Most guidelines and efforts to reduce transfusion focus on the decision to transfuse—specifically, a transfusion threshold or trigger of 7.0 to 8.0 g/dL Hb.[2,12–14] Equally important but less discussed is the amount of blood to transfuse after the decision to transfuse has been made. There has been some work on limiting the practice of routinely transfusing two units of red cells rather than one in the hemodynamically stable anemic patient.[15,16] However, there has been less focus on the goal Hb or transfusion target after a transfusion. The target Hb range in trials of restrictive transfusion practice is typically set at 9.0 g/dL. Final Hb before discharge can be used as an approximation of the clinician's transfusion target and used as a metric of the appropriate "dosing" of blood.[17,18] Final Hb concentrations above a set level may be considered as an "overtransfusion"—the tranfusion of more blood than necessary to obtain the accepted target goal of 9.0 g/dL. We sought to assess the epidemiology, risk factors, outcomes, and variation by surgeon in overtransfusion after colorectal and hepatobiliary surgery at our institution.

Methods

Patient selection

Patients undergoing major abdominal surgery on the hepatopancreatobiliary and colorectal services for benign and malignant disease at Johns Hopkins Hospital were identified between 2010 and 2013. Demographics, American Society of Anesthesiologists (ASA) class, Charlson comorbidity score, operation type, estimated blood loss (EBL), nadir and final Hb concentration, blood products transfused, inpatient complications, and length of stay (LOS) were collected.

Transfusion data

Transfusion data and Hb levels were obtained from IMPACT online (Haemonetics Corp., Braintree, Massachusetts), a prospective, audited, commercial blood management intelligence portal. Nadir Hb was used to define the transfusion trigger, whereas the final Hb measured, before discharge was used to represent the transfusion target. Hb trigger less than 8.0 g/dL and target less than 9.0 g/dL were considered appropriate based cutoff values established by prospective clinical trial data.[8–10,17] For the purposes of the current analyses, a discharge Hb $\geq$9.0 g/dL was considered an "overtransfusion" as it exceeds the established recommended target for transfusion based on multiple randomized controlled trials.[8–10,17]

Postoperative complications

International Classification of Disease, Clinical Modification, 9th Revision (ICD-9-CM) diagnosis codes acquired from the hospital billing database were used to identify inpatient postoperative complications, which included transient ischemic attack, cerebrovascular attack, myocardial infarction, ventilator-associated pneumonia, urinary tract infection, surgical site infection, sepsis, drug-resistant infection, *Clostridium difficile* infection, deep vein thrombosis, pulmonary embolism, and disseminated intravascular coagulation.

Statistical analysis

Continuous variables were presented as the median with interquartile range (IQR), where appropriate. Categorical variables were displayed as whole numbers and percentages. Baseline characteristics of the study population were summarized by operation type. Chi-squared tests were used for comparing categorical variables. Factors associated with transfusion and outcomes were analyzed using univariable and then multivariable regression models, which were constructed using a knowledge-based approach to variable selection. Modified-Poisson multiple regression models were used for binary outcomes, as these produce easily interpretable risk ratios, as opposed to odds ratios from logistic regression.[19] A multiple linear regression model was used for LOS. A 2-tailed P value of .05 was used as a cutoff for statistical significance. There were no missing data. Analysis was conducted with STATA version 13.1 (StataCorp LP, College Station, TX). The Johns Hopkins University Institutional Review Board approved the study.

Results

Baseline characteristics

A total of 2,905 patients who underwent surgery by 68 surgeons were identified. Overall 1,200 (41%) had pancreas surgery, 491 (17%) had a hepatobiliary operation, 779 (27%) had colorectal surgery, and 435 (15%) had other types of abdominal operation, the most commonly small bowel resections, mesenteric operations, and hernia repairs. Among all patients, 895 (31%) received a red blood cell transfusion during their hospitalization. Specifically, 17.2% of patients received an intraoperative blood transfusion (n = 500), whereas 21.9% received a postoperative blood transfusion (n = 636). Furthermore, 241 patients received both an intraoperative and postoperative blood transfusion. The percentage of patients who received a transfusion varied by operation type: 459 of 1,200 (38%) pancreatic, 122 of 491 (25%) hepatobiliary, 186 of 779 (24%) colorectal, and 128 of 435 (29%) other abdominal

($P < .001$). Fifty-four surgeons operated on a patient who was transfused. Subsequent analyses focused on those patients who received a red cell transfusion.

Baseline characteristics of the 895 patients who received a red blood cell transfusion were tabulated by operation (Table 1). Median age was 64 (IQR 53 to 72). A total of 454 patients were men (51%) and 441 were women (49%), which did not vary by operation type ($P = .198$). Race varied by operation, with a higher proportion of non-Hispanic whites for pancreatic (367 [80%]) and hepatobiliary (94 [77%]) operations than colorectal (132 [71%]) or other abdominal (76 [59%]) cases ($P < .001$). ASA class and Charlson comorbidity score were used as measures of comorbidity. Median ASA class was 3 (IQR 3 to 3), which varied between operation types: pancreas, 3 (IQR 2 to 3); hepatobiliary, 3 (IQR 3 to 3); colorectal, 3 (IQR 3 to 3); other abdominal, 3 (IQR 3 to 3; $P < .001$). Median Charlson comorbidity score was 4 (IQR 2–6), which varied between operation types: pancreas, 5 (IQR 2 to 7); hepatobiliary, 6 (IQR 3 to 7); colorectal, 4 (IQR 2 to 6); other abdominal, 2 (IQR 1 to 6; $P < .001$). Overall 584 patients had an operation for malignancy (65%), which varied markedly by operation type: pancreas, 339 (74%); hepatobiliary, 103 (84%); colorectal, 112 (60%); other abdominal, 30 (23%; $P < .001$). Median EBL varied significantly by operation type, with higher operative blood losses for pancreatic and hepatobiliary operations: pancreas, 850 cc (IQR 500 to 1,500 cc); hepatobiliary, 800 cc (IQR 450 to 1,500 cc); colorectal, 400 cc (IQR 150 to 900 cc); other abdominal, 300 cc (IQR 100 to 700 cc; $P < .001$). Overall 258 patients (29%) also received a nonred cell blood product transfusion, which did not vary by operation type ($P = .129$).

Transfusion trigger and units transfused

There was significant variation in the transfusion trigger by operation type: pancreas, 7.5 g/dL (IQR 7.0 to 8.2 g/dL); hepatobiliary, 7.4 g/dL (IQR 7.0 to 8.1 g/dL); colorectal, 7.1 g/dL (IQR 6.7 to 7.7 g/dL); other abdominal, 7.0 g/dL (IQR 6.5 to 7.4 g/dL; $P < .001$; Fig. 1).

The median number of packed red blood cell units transfused was 2 (IQR 2 to 4), which varied significantly by operation type: pancreas, 2 (IQR 2 to 4); hepatobiliary, 2 (IQR 1 to 4); colorectal, 2 (IQR 2 to 4); other abdominal, 3

Table 1 Characteristics of patients those who received red cell transfusions, n (%)

	Operation type					
Characteristic	Pancreas	Hepatobiliary	Colorectal	Other abdominal	Total	*P* value
Total	459 (100)	122 (100)	186 (100)	128 (100)	895 (100)	
Age						.001
<65	203 (44)	75 (61)	110 (59)	76 (59)	464 (52)	
65–79	213 (46)	39 (32)	65 (35)	42 (33)	359 (40)	
≥80	43 (9)	8 (7)	11 (6)	10 (8)	72 (8)	
Gender						.198
Male	234 (51)	65 (53)	83 (45)	72 (56)	454 (51)	
Female	225 (49)	57 (47)	103 (55)	56 (44)	441 (49)	
Race						<.001
White	367 (80)	94 (77)	132 (71)	76 (59)	669 (75)	
Black	42 (9)	14 (11)	39 (21)	39 (30)	134 (15)	
Asian	15 (3)	7 (6)	5 (3)	1 (1)	28 (3)	
Hispanic	4 (1)	0 (0)	0 (0)	1 (1)	5 (1)	
Other	31 (7)	7 (6)	10 (5)	11 (9)	59 (7)	
ASA Class						<.001
1	2 (0)	0 (0)	1 (1)	0 (0)	3 (0)	
2	113 (25)	22 (18)	40 (22)	30 (23)	205 (23)	
3	325 (71)	97 (80)	130 (70)	67 (52)	619 (69)	
4	19 (4)	3 (2)	15 (8)	26 (20)	63 (7)	
5	0 (0)	0 (0)	0 (0)	5 (4)	5 (1)	
Charlson Score						<.0001
1–2	76 (17)	12 (10)	35 (19)	50 (39)	173 (19)	
3–5	155 (34)	36 (30)	68 (37)	44 (34)	303 (34)	
≥6	228 (50)	74 (61)	83 (45)	34 (27)	419 (47)	
Malignancy	339 (74)	103 (84)	112 (60)	30 (23)	584 (65)	<.001
EBL						<.001
<500	106 (23)	33 (27)	100 (54)	75 (59)	314 (35)	
500-999	137 (30)	41 (34)	47 (25)	32 (25)	257 (29)	
1000–1999	158 (34)	29 (24)	33 (18)	14 (11)	234 (26)	
≥2000	58 (13)	19 (16)	6 (3)	7 (5)	90 (10)	
Other Blood Products	135 (29)	37 (30)	42 (23)	44 (34)	258 (29)	.129

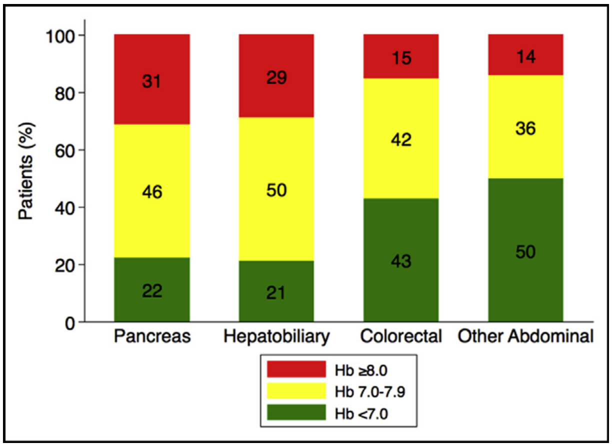

Figure 1 Transfusion trigger (nadir Hb) among transfused patients by operation type.

(IQR 2 to 6; $P < .001$ by analysis of variance [ANOVA]). Overall 208 patients (23%) received only one unit of red cells, whereas the remaining 687 patients (77%) received 2 or more. Seventy-one patients (8%) received a massive transfusion of 10 or more units.

Transfusion target

There was also wide variation in final Hb (transfusion target) among patients who received a transfusion, with a median of 9.2 g/dL (IQR 8.5 to 9.9 g/dL) and a range of 6.0 to 14.1 g/dL (Fig. 2). Among the 895 patients who received a red blood cell transfusion, 512 (57%) had a transfusion target of 9.0 g/dL or higher and therefore were categorized as having been "overtransfused." There was significant variation in overtransfusion by operation type: pancreas, 286 of 459 (62%); hepatobiliary, 69 of 122 (57%); colorectal, 90 of 186 (48%); other abdominal: 67 of 128 (52%; $P = .007$).

Potential risk factors for overtransfusion were assessed using univariable and then multivariable modified-Poisson regression (Table 2). These candidate risk factors included baseline characteristics, such as operation type, age, sex, race, ASA class, Charlson comorbidity score, and presence of malignancy. The surgical team had some degree of control over other potentially modifiable risk factors, including EBL, transfusion trigger, units transfused, and other blood products transfused.

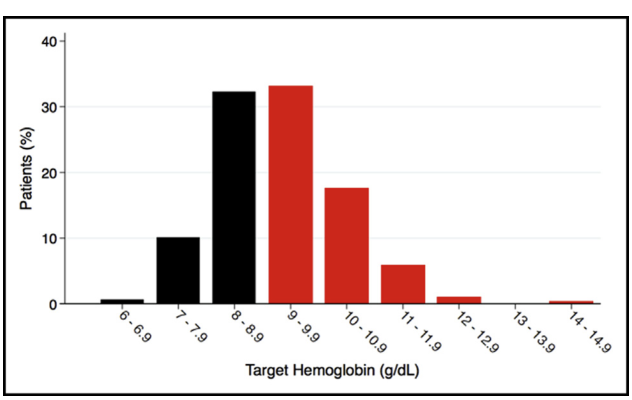

Figure 2 Final Hb (transfusion target) among transfused patients. Hb $\geq$9.0 g/dL constitutes an overtransfusion and is shown in red. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

On univariate analysis, pancreatic surgery had 1.29 times the risk for overtransfusion vs colorectal surgery (95% confidence interval [CI] 1.09 to 1.52, $P = .003$), whereas hepatobiliary and other abdominal surgery were not significantly different (both $P > .05$). Older age, race, ASA class, Charlson comorbidity score, and malignancy were not significant risk factors (all $P > .05$). Among potentially modifiable risk factors, increasing EBL and transfusion of nonred cell blood products were not risk factors for overtransfusion (both $P > .05$). However, a transfusion trigger of $\geq$8 g/dL Hb was associated with 1.46 times the risk of overtransfusion compared with a trigger of less than 7 g/dL (95% CI 1.27 to 1.67, $P < .001$). Furthermore, patients who received more than one unit of blood had 1.33 times the risk of overtransfusion compared with those patients who only received one unit (95% CI 1.13 to 1.56, $P < .001$).

After adjusting for all potential risk factors within a modified-Poisson regression model, patients who underwent pancreatic surgery remained at a higher risk of being overtransfused (relative risk [RR] 1.26 vs colorectal, 95% CI 1.07 to 1.48, $P = .07$), but no other baseline risk factors were significantly associated with overtransfusion. An elevated transfusion trigger of $\geq$8.0 g/dL Hb was, however, associated with 1.55 times the risk of overtransfusion compared with <7 g/dL (95% CI 1.34 to 1.80, $P < .001$). Also, transfusion of more than one unit was associated with 1.54 times the risk of overtransfusion compared with patients who only received one unit (95% CI 1.32 to 1.79, $P < .001$). Increasing blood loss was significantly associated with decreased risk of overtransfusion, but as this is closely tied to the transfusion trigger—greater losses drive Hb lower and therefore should decrease the risk of blood overtransfusion—this was not analyzed further as a modifiable risk factor.

Overtransfusion and perioperative outcomes

Complications were tabulated by operation type (Table 3). A total of 289 PRBC transfused patients (32%) experienced at least one complication, which varied by operation type: pancreas: 127 (28%), hepatobiliary: 29 (24%), colorectal: 66 (35%), and other abdominal: 67 (52%; $P < .001$). The most common complications were surgical site infection (116, 13%), sepsis (62, 7%), and *Clostridium difficile* colitis (50, 6%).

The association between overtransfusion and patient outcomes was assessed using a multivariable modified-Poisson regression model that adjusted for all characteristics listed in Table 2, except for transfusion trigger and number of units transfused, as these are so closely associated with overtransfusion. Patients with appropriate transfusion targets

Table 2 Risk factors for overtransfusion using univariable and multivariable modified Poisson regression

	Univariable			Adjusted		
	RR	95% CI	*P* value	RR	95% CI	*P* value
Organ			.011			
Pancreas	1.29	1.09–1.52	.003	1.26	1.07–1.48	.007
Hepatobiliary	1.17	.94–1.45	.155	1.18	.95–1.46	.134
Colorectal	1			1		
Other abdominal	1.08	.87–1.35	.488	1.06	.85–1.32	.601
Age, years			.410			
<65	1			1		
65–79	1.06	.94–1.19	.371	1	.88–1.13	.998
≥80	1.13	.93–1.37	.229	1.02	.84–1.25	.818
Male	1.08	.97–1.21	.166	1.05	.93–1.17	.454
Race			.154			
Non-Hispanic White	1			1		
Black	.88	.74–1.06	.178	.96	.80–1.15	.663
Asian	1.18	.91–1.54	.213	1.20	.95–1.53	.132
Hispanic	1.39	.89–2.17	.142	1.37	.93–2.03	.110
Other	1.09	.89–1.34	.403	1.19	.97–1.45	.089
ASA			.329			
1–2	1			1		
3	.91	.80–1.03	.142	.94	.82–1.07	.364
4–5	.91	.72–1.15	.425	.95	.75–1.21	.676
Charlson Score						
1–2	1			1		
3–5	.97	.85–1.11	.693	1.02	.84–1.24	.820
≥6	1.01	.87–1.17	.894	.95	.76–1.19	.660
Malignant	1.04	.92–1.18	.490	1.07	.89–1.27	.478
EBL			.921			
<500	1			1		
500–999	1.02	.88–1.17	.829	.93	.81–1.07	.318
1,000–1,999	1.03	.89–1.19	.662	.85	.73–.99	.036
≥2,000	.96	.78–1.19	.709	.76	.60–.95	.015
Trigger			<.001			
<7.0	1			1		
7.0–7.9	.95	.82–1.10	.501	.96	.83–1.12	.594
≥8.0	1.46	1.27–1.67	<.001	1.55	1.34–1.80	<.001
>1 Unit	1.33	1.13–1.56	<.001	1.54	1.32–1.79	<.001
Other blood products	.97	.85–1.10	.596	.92	.80–1.05	.216

ASA = American Society of Anesthesiologists; EBL = estimated blood loss.

had no excess risk of complications (a composite of any of the 12 morbid outcomes) compared with those who were overtransfused (RR 1.12, 95% CI .93 to 1.34, $P = .240$). Iterative analyses of separate regression models for each of the individual complications listed in Table 3 revealed no significant associations with overtransfusion (all $P > .05$). In addition, patients who had appropriate transfusion targets did not have a different LOS compared with patients who were overtransfused (1.35 days longer stay, 95% CI .22 days shorter to 2.92 days longer, $P = .092$ using multiple linear regression).

Variation by surgeon

Additional analyses were performed to assess transfusion patterns among the 26 surgeons who transfused at least 5 patients. Number of patients transfused ranged from 5 to 194, with a median of 22 (IQR 11 to 34). The proportion of overtransfused patients by surgeon ranged from 0% to 80%, with a median of 54% (IQR 50% to 61%) and significant variation among surgeons ($P = .003$ by chi-square test; Fig. 3).

Modifiable risk factors for overtransfusion from the multiple regression model included increased transfusion trigger and more than one unit transfused. Among the 26 surgeons who transfused at least 5 patients, the proportion of patients who were transfused at a trigger of ≥8.0 g/dL Hb ranged from 0% to 39% with a median of 30% (IQR 12% to 38%) and varied considerably among surgeons ($P < .001$ by chi-square test; Fig. 4). In contrast, while the proportion of patients who received more than one unit of red cells ranged from 54% to 100%, with a median of

Table 3 Postoperative inpatient complications by operation type, n(%)

Characteristic	Operation type				Total	*P* value
	Pancreas	Hepatobiliary	Colorectal	Other abdominal		
n	459 (100)	122 (100)	186 (100)	128 (100)	895 (100)	
SSI	55 (12)	11 (9)	27 (15)	23 (18)	116 (13)	.150
Pneumonia	10 (2)	3 (2)	3 (2)	7 (5)	23 (3)	.154
UTI	15 (3)	3 (2)	5 (3)	7 (5)	30 (3)	.506
Sepsis	26 (6)	5 (4)	13 (7)	18 (14)	62 (7)	.005
C diff	20 (4)	3 (2)	10 (5)	17 (13)	50 (6)	<.001
Drug Resistant Infection	4 (1)	1 (1)	3 (2)	4 (3)	12 (1)	.241
DIC	16 (3)	9 (7)	8 (4)	10 (8)	43 (5)	.105
DVT	6 (1)	4 (3)	10 (5)	12 (9)	32 (4)	<.001
PE	8 (2)	2 (2)	5 (3)	3 (2)	18 (2)	.860
VTE	13 (3)	4 (3)	13 (7)	14 (11)	44 (5)	.001
MI	6 (1)	1 (1)	5 (3)	3 (2)	15 (2)	.489
CVA	0 (0)	0 (0)	2 (1)	3 (2)	5 (1)	.009
Any Complication	127 (28)	29 (24)	66 (35)	67 (52)	289 (32)	<.001

C diff = *Clostridium difficile* colitis; CVA = cerebrovascular accident; DIC = disseminated intravascular coagulation; DVT = deep venous thrombosis; MI = myocardial infarction; PE = pulmonary embolism; SSI = surgical site infection; UTI = urinary tract infection; VTE = venous thromboembolism.

76% (IQR 70% to 82%), transfusion of more than one unit did not vary significantly among surgeons (*P* = .129 by chi-square test; Fig. 5).

Potential units saved

A simulation was run to determine the potential number of units saved had surgeons transfused to an appropriate Hb target of less than 9.0 g/dL. For each patient, the number of units that could have been withheld to arrive at a target of less than 9.0 g/dL was calculated, using 1.0 g/dL Hb per unit of red cells as a rough approximation (ie, target Hb 9.0 to 9.9 g/dL = 1 unit, 10.0 to 10.9 = 2 units). Using this approximation, 741 units could have been saved among the 895 transfused patients or an average of .8 units per patient. These 741 units accounted for 20% of the 3,774 total units transfused.

Comments

Optimal transfusion practice is critical to reducing risk, improving outcomes, and reducing cost. A robust evidence base has demonstrated the adverse outcomes associated with blood transfusion and the benefits of restrictive transfusion practice.[2,4–10] Accordingly, several major

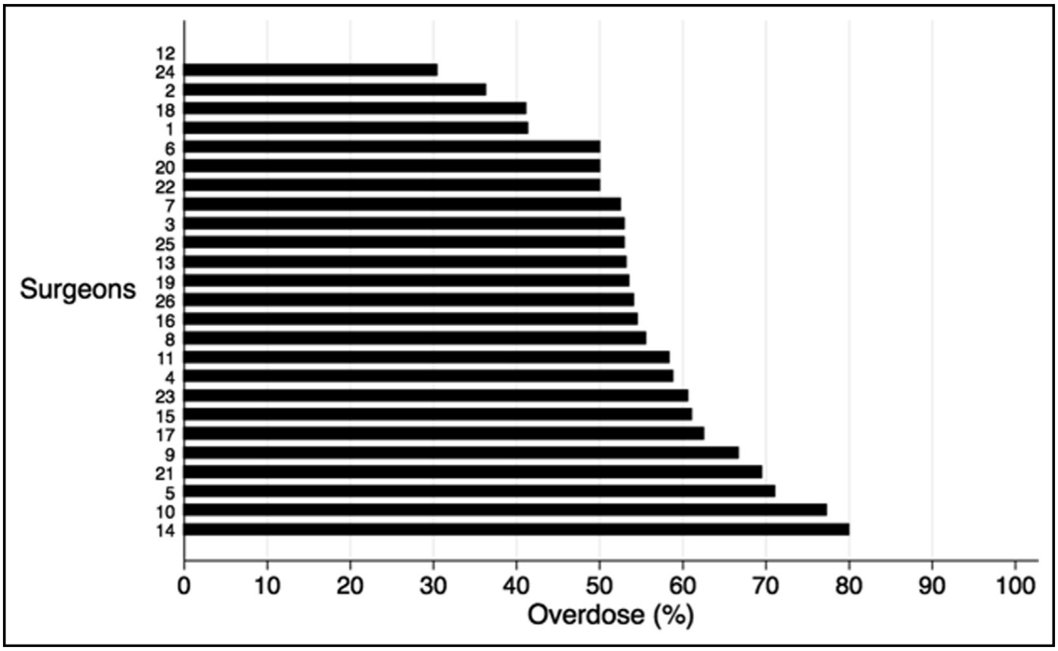

Figure 3 Variation in overtransfusion between surgeons. Surgeons with fewer than 5 transfused patients were excluded.

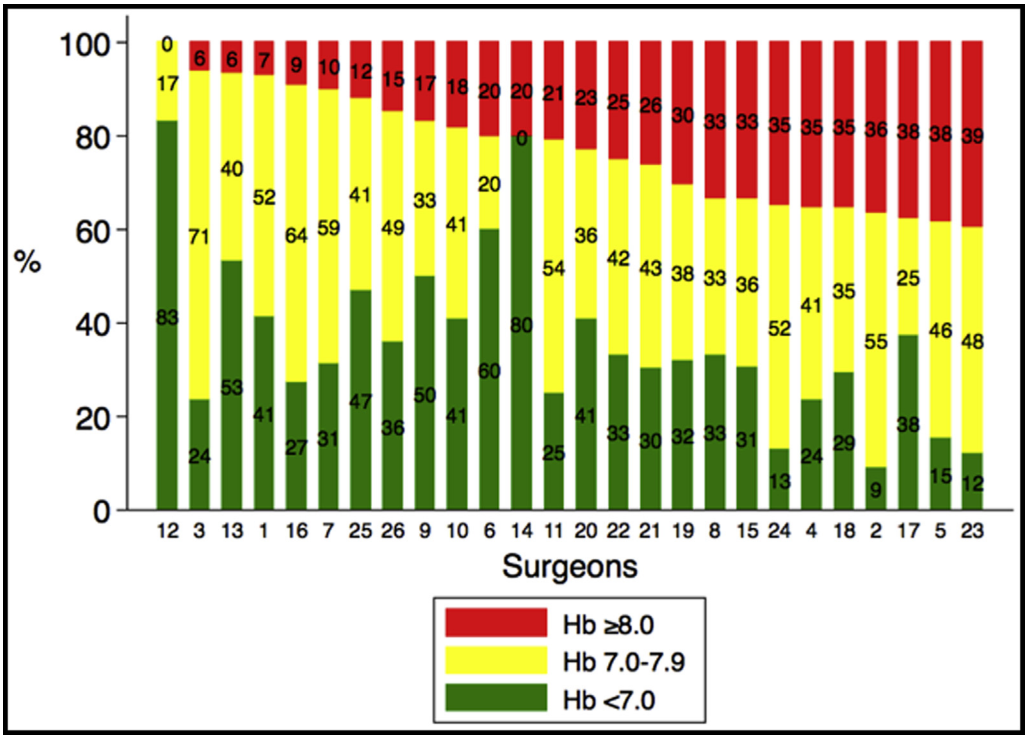

Figure 4 Variation in transfusion trigger between surgeons. Surgeons with fewer than 5 transfused patients were excluded.

societies have published clinical practice guidelines for blood transfusion that emphasize a restrictive transfusion strategy.[2,20–22] Hospitals are increasingly assessing physician compliance with clinical practice guidelines.[13] Rather than looking at the proportion of patients transfused or average number of units transfused, which vary based on the type of operation performed, the patient population, and the EBL, Frank et al[17] has proposed that assessing compliance with agreed on transfusion triggers and targets will result in a more accurate and fair comparison of physicians for appropriate blood utilization.

The major clinical trials advocating a restrictive transfusion practice establish either a Hb range to maintain (7.0 to 9.0 g/dL in the trial of transfusion requirement in critical care [TRICC] trial in intensive care patients and the gastrointestinal bleeding study by Villanueva et al[10]) or specify a Hb trigger and a practice of transfusing one unit at a time until this trigger is surpassed (Hb of 8.0 g/dL in

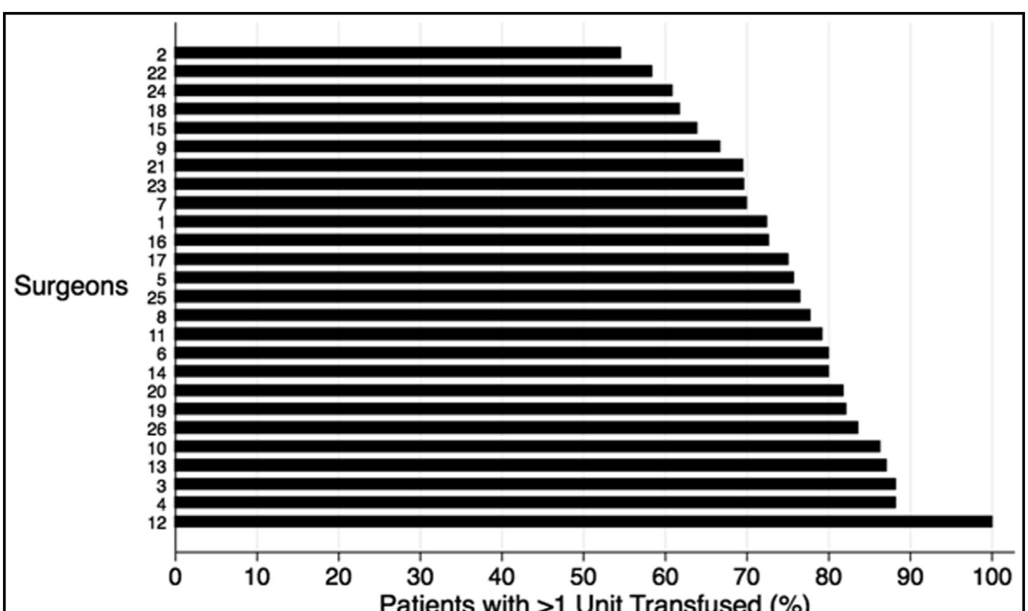

Figure 5 Variation in transfusion of more than one unit between surgeons. Surgeons with fewer than 5 transfused patients were excluded.

the transfusion trigger trial for functional outcomes in cardiovascular patients undergoing surgical hip fracture repair (FOCUS)[9] and hematocrit of 24% in the transfusion requirement after cardiac surgery (TRACS) trial,[8] both of which roughly equate to an upper Hb limit of 9.0 g/dL). Most discussion of these trials has focused on the decision to transfuse, which is determined by the pretransfusion Hb threshold, or trigger, rather than the dose of blood, which determines the post-transfusion Hb, or target. Based on these studies, Johns Hopkins Hospital has established a benchmark that a Hb less than 8.0 g/dL constitutes a restrictive trigger and a Hb less than 9.0 g/dL constitutes a restrictive target.

This article is one of the first to analyze red blood cell transfusion practice after surgery through the lens of transfusion targets[17,18] and the first to assess the risk factors for and outcomes for patients in whom the restrictive Hb target is exceeded. Fully 57% of colorectal and hepatobiliary surgical patients in this study were discharged with a Hb $\geq$9.0 g/dL and therefore received a red cell overtransfusion. Patients who were transfused with a restrictive target had equivalent complications and LOS compared with those with a liberal target (overtransfusion), consistent with multiple randomized controlled trials.[8–10] Given that patients with Hb targets $\geq$9 g/dL did not have better outcomes, there is no justification for the risk and cost of such excessive blood utilization.

Key independent risk factors for overtransfusion in a multivariable regression model included transfusing at a liberal Hb trigger of $\geq$8.0 g/dL and transfusion of more than one unit of red cells during the hospital stay. Other groups have also found that limiting transfusion to one unit at a time can decrease the total number of units transfused.[15,16] There was significant variation between surgeons in the frequency of overtransfusion, ranging from 0% to 80%. There was also significant variation between surgeons in the frequency of transfusing at a liberal trigger of $\geq$8.0 g/dL Hb, a key risk factor for overtransfusion, ranging from 0% to 39%. This variation suggests the opportunity for improvement by standardizing care in line with a clinical practice guideline. We estimate that had surgeons strictly adhered to appropriate transfusion targets, .8 units per transfused patient would have been saved, or 20% of all units given. To our knowledge, this is the first study to assess blood savings based on Hb target, whereas most previous studies have focused on Hb trigger.

A limitation of this study is that the particular circumstances of each transfusion were not studied. We used the lowest recorded Hb as the transfusion trigger, but other clinical triggers such as hemodynamic instability may have driven the decision to transfuse in some patients. In these patients, what may appear to be an inappropriate transfusion based on Hb levels might actually have been entirely appropriate and even lifesaving. Similarly, the transfusion may have occurred at a different time and at a higher Hb level than the nadir value, but this measurement error would only result in our study understating the use of liberal transfusion triggers. Finally, the complication data comes from an administrative database based on coding, which has been shown to underestimate complications compared with clinical databases.[23]

In conclusion, overtransfusion of red blood cell is frequent in colorectal and hepatobiliary surgery. It is commonly associated with liberal transfusion triggers and transfusion of multiple units. There is high variability between surgeons in some of these practices, suggesting an opportunity for improvement. More restrictive transfusion practice may reduce units transfused, decrease costs, and without compromising clinical outcomes.

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