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Choosing Wisely: Decreasing the incidence of perioperative blood transfusions in gynecologic oncology

Lauren S. Prescott [a,*,1], Jolyn S. Taylor [a], Ahmed Enbaya [a], Claire A. Marten [b], Keith N. Myers [a,2], Larissa A. Meyer [a], Pedro T. Ramirez [a], Charles F. Levenback [a], Diane C. Bodurka [a], Kathleen M. Schmeler [a]

[a] Department of Gynecologic Oncology and Reproductive Medicine, The University of Texas MD Anderson Cancer Center, Houston, TX 77030, USA
[b] Division of Pharmacy, The University of Texas MD Anderson Cancer Center, Houston, TX 77030, USA

HIGHLIGHTS

- Implementation of a transfusion reduction program is associated with a reduction in transfusion in gynecologic surgery.
- Transfusion reduction is associated with a significant institutional cost savings.
- Transfusion reduction is not associated with increased morbidity or mortality.

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ABSTRACT

Objective. To evaluate the efficacy and economic impact of a transfusion reduction initiative for patients undergoing gynecologic surgery.

Methods. We conducted a prospective healthcare improvement study to align transfusion practices with the American Society of Hematology's *Choosing Wisely*® campaign. Baseline transfusion rates were determined retrospectively for all major gynecologic surgical cases from 3/1/14 to 6/30/14. Data for the post-intervention period from 5/15/15 to 5/16/16 were captured prospectively. The primary outcome was transfusion within 72 h of surgery. Secondary outcomes included perioperative morbidity, mortality, number of units ordered per transfusion episode and cost.

Results. We identified 1281 surgical cases, 334 in the baseline and 947 in the post-implementation cohort. The baseline cohort was noted to have a higher median estimated blood loss (100 v. 75 mL, $P < 0.01$). Otherwise, there were no differences in clinical or perioperative characteristics between the two cohorts. The perioperative transfusion rate decreased from 24% to 11% (adjusted OR 0.27, 95% CI 0.16 to 0.45; $P < 0.001$). The perioperative laparotomy transfusion rate decreased from 48% to 23% (adjusted OR 0.21, 95% CI 0.12, 0.37; $P < 0.001$). The number of occurrences in which more than one unit of blood was ordered at a time decreased from 65% to 23%, $P < 0.001$. The incidence of surgical site infections declined in the post-intervention group, otherwise there were no differences in 30-day mortality, cardiac, venous thromboembolism or readmission rates between the groups. The projected cost savings was $161,112 over the 12-month intervention period.

Conclusions. Implementation of an educational based transfusion reduction program was associated with substantial reductions in perioperative transfusions and cost without significant changes in morbidity or mortality.

1. Introduction

Choosing Wisely® is an initiative developed by the American Board of Internal Medicine to identify tests or procedures that are often overutilized [1]. The *Choosing Wisely*® campaign has been adopted by many subspecialty societies to promote awareness of waste and potential harm through unnecessary testing. In 2013, the American Society of Hematology identified transfusions as one of their *Choosing Wisely*® targets. The society recommended against transfusing more than the

* Corresponding author at: Department of Obstetrics and Gynecology, Vanderbilt University Medical Center, 1161 Medical Center Drive, Nashville, TN 37232, USA.
E-mail address: lauren.prescott@vumc.org (L.S. Prescott).
[1] Present Address: Department of Obstetrics and Gynecology, Vanderbilt University Medical Center, Nashville TN 37212, USA.
[2] Present Address: School of Medicine, Temple University, Philadelphia, PA 19102, USA.

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minimal number of red blood cells necessary to alleviate symptoms of anemia or return a patient to a safe hemoglobin (hgb) range of 7 to 8 g/dL as well as to transfuse one unit of packed red blood cells (PRBCs) at a time in lieu of the traditional two units [2].

Patients with gynecologic cancer are at high risk of perioperative blood transfusions with reported rates as high as 41 to 77% [3,4]. Previous studies have demonstrated that blood transfusions are associated with increased perioperative morbidity and mortality [5–8]. Despite the relative frequency of perioperative blood transfusions in gynecologic oncology, there is limited published support on development of transfusion reduction initiatives and their efficacy.

Review of our transfusion data in the Department of Gynecologic Oncology and Reproductive Medicine at The University of Texas MD Anderson Cancer Center (MD Anderson) revealed that our perioperative transfusion rate of 24% was significantly above the national average rate of 13.8% and that we were non-compliant with national blood utilization recommendations [5,9,10]. We therefore designed and implemented a healthcare improvement initiative to decrease our perioperative transfusion rates and align practices with current evidence-based guidelines. The primary aim of our health care improvement initiative was to decrease our perioperative transfusion rates by 25% for patients undergoing gynecologic surgery. Our primary endpoint was receipt of transfusion within 72 h of surgery. Secondary endpoints included compliance with guidelines, perioperative morbidity, 30-day mortality, projected blood savings, and estimated cost savings.

2. Materials and methods

This study was approved by the MD Anderson Quality Improvement Assessment Board and this manuscript has been prepared in accordance to the Standards for Quality Improvement Reporting Excellence (SQUIRE 2.0) guidelines [11]. We utilized the Six Sigma Define, Measure, Analyze, Improve and Control model to design our intervention.

2.1. Context/intervention

MD Anderson is a tertiary care academic cancer center in Houston, Texas. A multidisciplinary team was assembled including physicians from the Departments of Gynecologic Oncology & Reproductive Medicine and Anesthesiology & Perioperative Medicine, as well as advanced practice providers, nurses and administrators. The multidisciplinary team was assembled and had regular meetings over several months from July 2014 to April 2015 to determine the optimal transfusion guidelines for our patient population, as well as to develop an education and implementation plan. This team developed transfusion guidelines in adherence with current evidence-based medicine and the *Choosing Wisely*® campaign. These guidelines included the following recommendations:

1. Avoid transfusions for asymptomatic patients with hgb greater than or equal to 7 g/dL
2. Transfuse one unit of PRBCs at a time in lieu of the traditional two units
3. Exceptions: acute or massive hemorrhage, clinical trial requiring higher hgb level for full-dose treatment, acute myocardial infarction or coronary syndrome or symptomatic anemia

This plan was approved by our patient care and operations team in November of 2014 which evaluates and approves all quality improvement initiates in our department. Consensus was reached among 20 gynecologic oncology faculties at a faculty retreat in March 2015 to implement and adhere to guidelines. The guidelines and rationale for change in practice were disseminated to trainees, advanced practice providers, nursing staff, as well as anesthesia and emergency room providers through a series of educational presentations as well as targeted outreach. This included a Grand Rounds presentation to the Department of Gynecologic Oncology & Reproductive Medicine by an outside clinical content expert, journal club with focus on restrictive transfusion protocol and small focus group educational presentations. Monthly morbidity and mortality conferences were utilized to provide feedback to the department faculty and trainees on transfusion rates and specific cases that were not in alignment with recommended practice.

2.2. Outcome measures/analysis

Baseline transfusion rates were retrospectively collected for all major gynecologic surgical cases from 3/1/14 to 6/30/14. Data for the post-intervention period from 5/15/15 to 5/16/16 were captured prospectively. Study data were collected and managed using REDCap electronic data capture hosted at MD Anderson [12]. The baseline time frame was chosen as it marked a period prior to initiation of discussions regarding our transfusion rate and implementation of the multidisciplinary team tasked to decrease the transfusion rate. The post-intervention period was chosen to begin after completion of all educational outreach. The gap between 6/30/14 and 5/15/15 accounts for our transition period to develop the guidelines and disseminate the information to all stakeholders.

Patients were excluded if they had a minor surgery defined as dilation and curettage, vaginal biopsies, laser ablations of vagina, vulva, colposcopy, wide local excisions of the vagina or vulva, exam under anesthesia or tandem and ovoid placement. Patients were also excluded if they had a non-gynecologic malignancy and their primary postoperative care was provided by another service. Patients who had a combined surgical case with another service admitted to the gynecologic oncology service were included. Emergency cases and patients admitted prior to surgery were included.

Our primary endpoint was perioperative transfusion of PRBCs which was defined as receipt of transfusion of PRBCs during the operative procedure or within 72 h postoperatively. Secondary endpoints included compliance with guidelines, perioperative morbidity, mortality, and estimated cost savings. All other complications including mortality were within 30 days of surgery. Perioperative morbidity was measured by an adverse event within 30 days of surgery. Adverse events monitored were cardiac arrhythmias, myocardial infarctions (MI), surgical site infections, wound disruptions/dehiscence, venous thromboembolism (VTE), length of stay, readmission and death. Surgical site infections were defined as an infection of the surgical incision or organ space requiring antibiotics within 30 days of surgery [13]. Preoperative hgb was obtained within 30 days of surgery. Race and ethnicity were extracted from the medical record and were self-reported by patients. Neoadjuvant and preoperative radiation were defined as receipt of treatment within 60 days prior to surgery. Preoperative blood transfusion was defined as receipt of blood transfusion administered within 30 days prior to surgery. This includes transfusions initiated inpatient or in the Emergency Room same day of surgery but prior to transfer to operating room.

Compliance with transfusion guidelines was monitored by monthly review of transfusion data with identification of patients who received an intraoperative transfusion, postoperative blood transfusion with hgb >7, as well as individuals in which more than one unit of PRBCs was ordered at a time. The cost of one unit of blood was estimated at $761 based on the mean transfusion cost calculated using activity-based costing previously published by Shander et al. [14] Projected blood savings was calculated by estimating the monthly number of units saved after implementation multiplied by the estimated cost of unit of blood.

Demographic information, perioperative variables and transfusion rates were compared between the baseline and post-intervention cohorts using Chi-square, Fisher exact and Kruskal-Wallis descriptive statistics. Multivariable exact logistic regression was used to model the logit of the probability of transfusion. A saturated model including all factors with a $P \leq 0.20$ was built and backward elimination was used

in a multivariable analysis to construct a parsimonious model, removing factors one at a time until all remaining factors remained statistically significant. All analyses were performed using STATA™ 13.0 for Macintosh (StatCorp LP, College Station, Texas). Statistical process control (SPC) charts study how a process changes over time. They are utilized in quality improvement to determine the impact of an intervention on an on-going process. We utilized SPC charts to identify and graphically display variation in transfusion rate and the change in transfusion after implementation of our TRI. The SPC charts were created using Excel.

3. Results

We identified 1281 surgical cases, 334 in the baseline cohort and 947 in the post-implementation cohort. Patient demographic and clinical characteristics are listed in Table 1. Perioperative characteristics and surgical procedures performed are listed in Table 2. There were no differences between the two cohorts with regards to age, body mass index (BMI), preoperative chemotherapy, preoperative radiation, ASA class, race/ethnicity, presence of malignancy, cancer type, surgical approach or emergent surgery. The baseline cohort was noted to have a statistically higher median estimated blood loss (100 v. 75 mL; $P < 0.01$). Otherwise, there were no differences in perioperative variables between the two cohorts.

In both cohorts, laparotomy was the most common route of surgery (165 (49%) v. 420 (44%)) followed by laparoscopy (125 (37%) v. 390 (41%)). There were 253 (56%) patients identified with malignancy in the baseline and 656 (69%) in the post-intervention cohort. Ovarian cancer was the most common malignancy encountered in both cohorts (123 (49%) v. 283 (43%)). The prevalence of medical comorbidities including congestive heart failure, chronic obstructive pulmonary disease, diabetes, hypertension, chronic kidney disease, myocardial infarction, VTE, and solid tumor was not statistically different between the two cohorts. The median Charlson Comorbidity Index (CCI) was 3 for both cohorts.

After implementation of our transfusion reduction initiative, the perioperative transfusion rate decreased from 81/334 (24%) to 102/947 (11%), (unadjusted OR 0.38, 95% CI 0.27 to 0.52; $P < 0.001$). This equates to a relative risk reduction (RRR) of 53%. In the multivariable analysis after controlling for key clinical and perioperative variables our transfusion reduction initiative was independently associated with a decrease in transfusion (adjusted OR 0.27, 95% CI 0.16 to 0.45; $P < 0.001$) (Table 5). Fig. 1 depicts the transfusion rate over time using a statistical process control chart. Our transfusion reduction initiative resulted in a reduction in the mean and amplitude of the transfusion rate, consistent with improved process control.

Table 1
Demographic characteristics.

Characteristic	Baseline $N = 334$ (%)	Post-intervention $N = 947$ (%)	P-value[a]
Age, median (IQR), years	57 (46–66)	57 (45–66)	0.8
BMI, median (IQR), kg/m^2	29 (24–34)	29 (24–35)	1.0
Neoadjuvant chemotherapy, no. (%)	59 (18)	141 (15)	0.26
Missing	0	2	
Preoperative radiation, no. (%)	7 (2)	15 (2)	0.62
Missing	0	2	
Current smoker, no. (%)	31 (9)	64 (7)	0.15
ASA class, no. (%)			0.60
1	0	5 (1)	
2	60 (18)	182 (19)	
3	261 (79)	729 (78)	
4	10 (3)	23 (3)	
Missing	3	8	
Charlson comorbidity index score, no. (%)			0.28
0–3	220 (66)	656 (69)	
≥4	114 (34)	291 (31)	
Race/ethnicity, no. (%)			0.66
White	229 (69)	662 (70)	
Hispanic	45 (13)	138 (15)	
Black	35 (11)	91 (10)	
Asian	19 (6)	47 (5)	
Other/unknown	6 (2)	9 (1)	
Neoplasm, no. (%)			0.08
Benign	76 (23)	268 (28)	
Malignant	253 (76)	656 (69)	
Low malignant potential (LMP)	5 (2)	23 (2)	
Cancer type, no. (%)[b]			
Ovary	123 (49)	283 (43)	0.23
Uterus	81 (32)	240 (37)	
Cervix	26 (10)	66 (10)	
Vulva/vagina	12 (5)	49 (7)	
Other/unknown	8 (3)	10 (2)	
Dual primary	3 (1)	8 (1)	
Comorbidities			
Congestive heart failure	1 (0)	6 (0.6)	0.68
Chronic obstructive pulmonary disease	6 (2)	15 (2)	0.80
Diabetes	49 (15)	135 (14)	0.86
Hypertension	124 (37)	390 (41)	0.22
Moderate to severe CKD	3 (0.9)	7 (1)	0.73
Myocardial infarction	5 (2)	10 (1)	0.56
Venous thromboembolism	11 (3)	49 (5)	0.18
Solid tumor	65 (20)	148 (16)	0.12

Abbreviations: IQR, interquartile range; BMI, body mass index; ASA, American Society of Anesthesiologists; EBL, estimated blood loss.

[a] Fisher's exact tests for categorical variables and Kruskal-Wallis to compare medians between groups for continuous variables.

[b] Definition of ovarian cancer includes individuals with primary peritoneal and fallopian tube cancer. Dual primaries and LMP tumors were are not included in individual counts of cancer type. All dual primaries were ovarian and endometrial cancer with exception of one patient who had vulva and fallopian tube cancers.

Table 2
Perioperative characteristics and surgical procedures.

	Baseline N = 334 (%)	Post-intervention N = 947 (%)	P-value[a]
Preoperative blood transfusion, no. (%)	7 (2)	27 (3)	0.56
Preoperative hgb, g/dL			0.74
<7	0 (0)	2 (0)	
≥7 to 10	35 (11)	88 (9)	
≥10	298 (89)	856 (90)	
Missing	1	1	
Surgical time, median (IQR), min	164 (111–235)	154 (102–225)	0.13
Missing	0	3	
EBL, median (IQR), mL	100 (40–300)	75 (25–200)	<0.01
Missing	0	1	
Surgical approach, no. (%)			0.41
Laparotomy	165 (49)	420 (44)	
Laparoscopy	125 (37)	390 (41)	
Robot	32 (10)	92 (10)	
Vulva/vaginal	12 (4)	45 (5)	
Non-elective surgery, no. (%)	13 (4)	53 (6)	0.25
Combined case, no. (%)	32 (10)	96 (10)	0.83
Exenteration	6 (2)	10 (1)	0.39
Liver resection	6 (2)	13 (1)	0.37
Cholecystectomy	0 (0)	5 (2)	0.08
Splenectomy	6 (2)	10 (1)	0.21
Urologic procedures			
Bladder resection	0 (0)	7 (1)	0.20
Urethral resection	1 (0)	2 (0)	1.00
Ureteral re-implantation	0 (0)	5 (1)	0.34
Nephrectomy	0 (0)	5 (1)	0.34
Lymphadenectomy			
Pelvic	86 (25)	188 (20)	0.03
Para-aortic	44 (13)	123 (13)	0.95
Inguinal	4 (1)	13 (1)	1.00
Bowel surgery	86 (26)	208 (22)	0.17

Abbreviations: hgb, hemoglobin; IQR, interquartile range; EBL, estimated blood loss.

[a] Fisher's exact tests for categorical variables and Kruskal-Wallis to compare medians between groups for continuous variables.

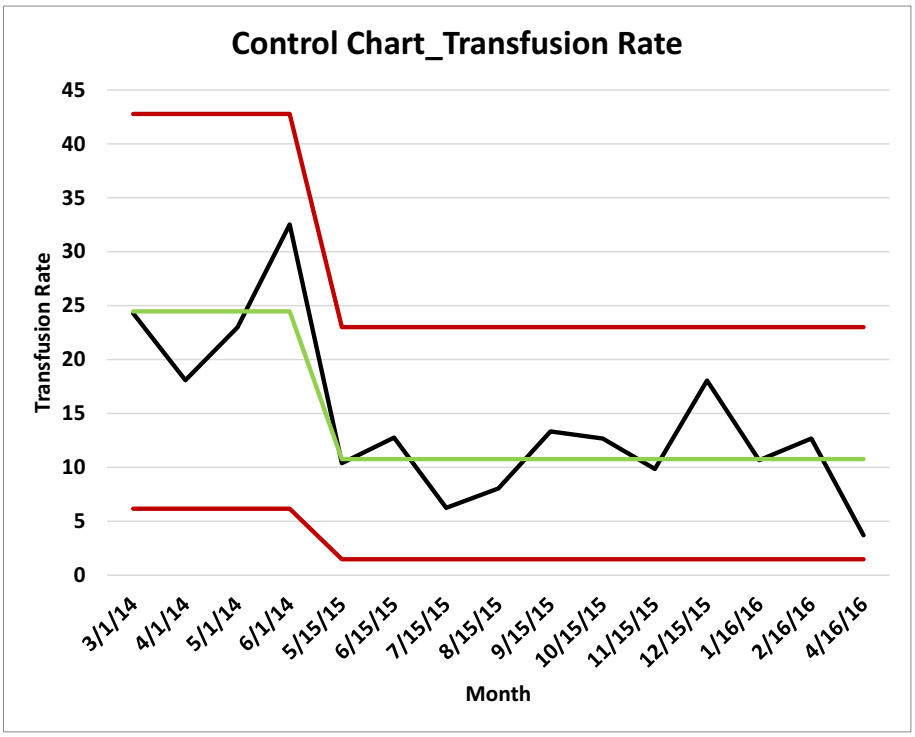

Fig. 1. Control Chart demonstrating monthly transfusion rate. The lower control limit (LCL) (red line) was defined as 3 standard deviations below the mean transfusion rate. The upper control limit (UCL) (red line) was defined as 3 standard deviations above the mean transfusion rate. The monthly transfusion rate is in black and the mean transfusion rate for the baseline period and post-intervention period is in green. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

We performed several subgroup analyses to determine if the decrease in transfusion rate would persist in different subcategories given the heterogeneity of our patient population and case selection (Table 4). We performed a multivariable analysis controlling for key clinical and perioperative variables (all factors with *P* value ≤0.20 on univariable analysis were included). The perioperative laparotomy transfusion rate decreased from 80/165 (48%) to 96/420 (23%), (adjusted OR 0.21, 95% CI 0.12, 0.37; $P < 0.001$). The transfusion rate for patients with malignancy decreased from 75/253 (30%) to 93/656 (14%), (adjusted OR 0.28, 95% CI 0.16, 0.48; P < 0.001). The transfusion rate declined for patients with ovarian cancer from 52/126 (41%) to 49/291 (17%), (adjusted OR 0.13, 95% CI 0.06, 0.27; $P < 0.001$). There was no difference in transfusion rates for other cancer types or surgical approaches. Intraoperative transfusion rates decreased from 39/334 (12%) to 59/947 (6%), (unadjusted OR 0.51, 95% CI 0.33 to 0.78; $P = 0.002$). Postoperative transfusion rates decreased from 67/334 (20%) to 58/947 (6%), (unadjusted OR 0.28, 95% CI 0.19 to 0.40; P < 0.001).

The incidence of complications is depicted in Table 3. Surgical site infections declined in the post-intervention group (11% v 8%, OR 0.63, 95% CI 0.42, 0.96; $P = 0.03$). There were no differences in 30-day mortality, cardiac or VTE rates between the groups. We subsequently identified 72/334 (22%) patients in the baseline cohort who received a transfusion who would not have received a transfusion if they were in the post-implementation cohort. This cohort was defined as individuals who received a blood transfusion with a postoperative hemoglobin nadir between 7 and 10 g/dL. Patients were excluded if the indication for transfusion was active bleeding or symptomatic anemia. We also identified 226/947 (24%) patients in the post-implementation cohort who did not receive a transfusion but may have prior to the guideline implementation. This cohort was defined as individuals who did not get a blood transfusion with a postoperative hgb nadir between 7 and 10 g/dL. We performed a subgroup analysis looking at perioperative outcomes between these two groups. The incidence of VTE was higher in the transfusion group (three v. zero events, $P = 0.012$). The incidence of surgical site infections was higher in transfusion group 15 (20.8%) v. 22 (9.7%), $P = 0.022$. Otherwise there were no differences in cardiac arrhythmias/MI, wound disruption/dehiscence, mortality or readmission.

3.1. Compliance

The number of occurrences in which more than one unit of blood was ordered at a time postoperatively declined from 67 (66%) to 22 (23%), $p <$

Table 3
Complications.

	Baseline N = 334 (%)	Post-intervention N = 947 (%)	P-value[a]
Cardiac arrhythmia/MI, no. (%)	2 (1)	5 (1)	1.00
Length of stay, median (IQR), days	2 (0–5)	1 (0–3)	<0.001
SSI, No. (%)	38 (11)	71 (8)	0.04
Wound disruption/dehiscence, no. (%)	19 (6)	37 (4)	0.08
Missing	0	3	
VTE, no. (%)	4 (1)	7 (1)	0.31
Mortality, no. (%)	4 (1)	3 (0)	0.08
Readmission, no. (%)	26 (8)	80 (9)	0.73

Abbreviations: MI, myocardial infarction; SSI, surgical site infection; VTE, venous thromboembolism.
[a] Fisher's exact tests for categorical variables and Kruskal-Wallis to compare medians between groups for continuous variables.

Table 4
Transfusion outcomes.

	Baseline N = 334 (%)	Post-Intervention N = 947(%)	P-value[a]
Transfusion[b]			
Perioperative	81 (24)	102 (11)	<0.001
Intraoperative	39 (12)	59 (6)	0.003
Postoperative	67 (20)	58 (6)	<0.001
No. of occurrences >1 unit ordered postop	66 (65)	22 (23)	<0.001
Postop hgb nadir, median (IQR)	9.1 (8–10.7)	9.9 (8.3–11.5)	<0.001
Missing	120	303	
Postop hgb nadir (transfused), median (IQR)[c]	7.9 (7.5–8.3)	7.2 (6.8–8.1)	<0.001
Postop hgb first (transfused), median (IQR)[c]	9.4 (8.4–10.8)	8.9 (7.8–10.1)	0.05
Occurrence of transfusion if cancer	75/253 (30)	93/656 (14)	<0.001
Occurrence of transfusion by cancer			
Ovary	51 (41)	49 (16)	<0.001
Uterus	13 (16)	31 (13)	0.46
Cervix	8 (31)	7 (11)	0.03
Vulva/vagina	0 (0)	5 (10)	0.57
Other/unknown	1 (14)	1 (7)	1.00
Occurrence of transfusion by surgical approach			
MIS	1/157 (1)	4/482 (1)	1.0
Laparotomy	80/165 (48)	96/420 (23)	<0.001
Vulva/vaginal	0/12 (0)	2/45 (4)	1.0

Abbreviations: IQR, interquartile range; hgb, hemoglobin.
[a] Fisher's exact tests for categorical variables and Kruskal-Wallis to compare medians between groups for continuous variables.
[b] There is overlap between these categories. Perioperative transfusion includes receipt of intraoperative or postoperative transfusion, intraoperative transfusion all intraoperative transfusions, and postoperative transfusion includes all postoperative transfusions.
[c] Calculations only include patients who received a perioperative blood transfusion.

0.001. The indications for transfusion were extracted from the medical record. Of the 58 patients in the post-implementation cohort who had postoperative transfusion, 38 patients had a transfusion for hgb < 7 and 20 had a transfusion for hgb > 7. Of these 20 cases, the indications for transfusion were appropriate in 7 cases: cardiac disease ($N = 1$), symptomatic anemia ($N = 5$), active bleeding (N = 1). Thirteen patients had transfusions that were deemed inappropriate per the guidelines.

3.2. Estimated cost savings

There were a total of 278 units transfused in the baseline time period of four months and 250 units transfused in post-intervention period of 12 months. This results in an estimated savings of 49 units of blood per month. Assuming a cost/unit of blood at $761, this intervention lead to a projected institutional cost savings of $13,426 per month and $161,112 over the 12-month intervention period.

4. Discussion

Perioperative transfusions in gynecologic surgery significantly decreased after implementation of an educational based transfusion reduction program in adherence with *Choosing Wisely*®. The pattern of transfusion reduction was observed across several subgroups and maintained over a 12-month period. Our intervention was associated with decreased variability in transfusion practices. We successfully transformed our practice from a high outlier to below the national average. This change in perioperative transfusion rate was mostly a reflection of the reduction in transfusion in the laparotomy cohort as the transfusion rates in the MIS cases remained low.

Research from the last decade has shown the relative safety of restrictive transfusion strategies. A 2012 Cochrane review including 19 trials and 6264 patients demonstrated that restrictive transfusion approaches decreased transfusion rates by 39% without compromising patient safety [15]. In fact, several studies have suggested worse perioperative and oncologic outcomes associated with blood transfusions [5,7,8]. This trend has been demonstrated across several surgical subspecialties including colorectal surgery and gynecologic oncology [5,7]. Restrictive transfusion practices have subsequently been endorsed by numerous medical and surgical societies and adopted nationwide [4,9,10,16–18].

However, despite the benefits of restrictive transfusion demonstrated across heterogeneous clinical settings, optimal blood transfusion management in some high-risk subpopulations remains controversial. The prevalence of anemia in oncology is high and the etiology multifactorial [19–21]. Numerous studies have demonstrated that anemia is a poor prognostic indicator of perioperative and oncologic outcomes. So, despite the lack of high evidence that transfusion reverses those outcomes, there is a bias in the field that transfusions are beneficial. This controversy of the appropriate transfusion management is reflected by the high variation in transfusion practices across providers. When we

Table 5
Multivariable regression analysis for the association between transfusion reduction initiative and transfusion.

	N (events)	Univariable			Multivariable		
		OR	95% CI	P-Value	OR	95% CI	P-value
Cohort							
Baseline	334 (81)		REF				
Post-intervention	947 (102)	0.38	0.27, 0.52	<0.001	0.27	0.16, 0.45	<0.001
Cancer type							
Vulva/vaginal	62 (5)		REF				
Ovary	442 (104)	5.82	3.67, 9.24	<0.001	1.18	0.56, 2.49	0.67
Cervix	92 (15)	3.80	1.90, 7.61	<0.001	3.12	1.02, 9.57	0.05
Uterus	331 (48)	3.04	1.84, 5.01	<0.001	0.92	0.40, 2.12	0.84
Preoperative transfusion	32 (13)	4.34	2.11, 9.00	<0.001			
Preoperative hgb, g/dL	1279 (182)	0.49	0.44, 0.55	<0.001	0.44	0.37, 0.52	<0.001
Surgical time (per hour)	1278 (183)	1.86	1.68, 2.06	<0.001	1.43	1.22, 1.69	<0.001
EBL (per 50 mL)	1280 (183)	1.28	1.23, 1.32	<0.001	1.20	1.15, 1.26	<0.001
Surgical approach							
MIS	639 (5)		REF				
Laparotomy	585 (176)	54.56	22.24, 133.88	<0.001	8.25	3.01, 22.66	<0.001
Vulva/vaginal	57 (2)	4.61	0.87, 24.32	0.072	3.27	0.43, 24.86	0.25
Elective surgery	1271 (167)	0.50	0.28, 0.90	0.021			
Charleston Comorbidity Index	1281 (183)	1.06	0.98, 1.15	0.117	1.22	1.08, 1.38	0.002

The multivariate model considered all variables with P ≤ 0.20 which included cohort, age, NACT, HTN, ASA class, race, malignancy, cancer type, preoperative transfusion, preoperative hemoglobin, surgical time, EBL, surgical approach, elective surgery, Charleston Comorbidity Index. A backward stepwise selection process was used to determine the final model. The final model included cohort, cancer type, preoperative hgb, surgical time, EBL, surgical approach and Charleston Comorbidity Index. MIS includes laparoscopy and robotic.

initiated this health care quality initiative, there was a paucity of oncologic-specific contemporary nationally adopted guidelines and wide variations in published practice patterns. The National Comprehensive Cancer Center Network (NCCN) has recently updated their guidelines and indications for red blood cell transfusion to reflect the national guidelines endorsed by the American Association of Blood Banks (AABB) [9,22]. However, even in the presence of well established guidelines, adherence to evidence-based medicine guidelines is often suboptimal. Lugtenberg et al. explored the barriers to adherence among Dutch general practitioners and identified wide variations in perceived barriers [23]. The most common barriers identified were lack of agreement with recommendation, organizational constraints, lack of knowledge regarding the recommendation and unclear and ambiguous guidelines and recommendations [23]. Likewise, Cabana et al. performed a systematic review identifying barriers to physician adherence to guidelines. The authors identified awareness, familiarity and agreement among the three most common barriers for adoption [24].

We sought to utilize education and awareness of practice to change behavior and transfusion practices within our department. In review of previously published transfusion reduction initiatives, the most robust transfusion reduction initiatives include provider education coupled with triggers to follow the guidelines as part of the electronic medical record [25–27]. The strengths of our transfusion reduction initiative include the ability to achieve consensus among a large group of gynecologic oncologists. This was enabled by the structure for quality improvement work that had been established in our practice at MD Anderson. We have a monthly committee meeting dedicated to patient care and safety issues as well as a semi-annual faculty retreat to allow for standardization and system change. We secured administrative support from the concept of the project and consensus was reached among faculty for implementation. Our intervention utilized a national initiative, the *Choosing Wisely*® campaign, to gather traction at our institution. Our approach was education based without the complexity of adding electronic decision support. We were able to enact change through education and transparency with our data. Previous studies have suggested that education alone is insufficient to cause significant change in behavior, however coupled with reinforcement through presentation of provider specific data at our monthly M&M conference, we were able to exhibit tangible change.

There are several limitations to our study. First, baseline data were collected retrospectively thereby potentially introducing bias. Second, this is a 'before and after' study design and temporal in nature, therefore there are factors that could not be controlled in this sequential, rather than concurrent comparison. The nature of this study design limits our interpretation of the data and ability to draw conclusions about causation. Furthermore, there were additional quality improvement initiatives ongoing during the same time period that might have contributed to the aforementioned outcomes including implementation of our enhanced recovery program and a surgical site reduction initiative. The estimated blood loss was noted to be lower in the post-implementation group. There are multiple factors that may have contributed to the decline in estimated blood loss including advances in surgical technique and improvements in goal directed fluid therapy as part of our enhanced recovery program that may have contributed to the decrease in EBL. Also, awareness of the negative association with transfusion may have increased perioperative awareness of hemostasis and intraoperative measures to decrease blood loss. Our study is also limited by the heterogeneity of cases. Currently, there is no published validated surgical complexity calculator for heterogeneous mix of surgical cases and therefore surgical approach and length of procedure were utilized as surrogate markers for complexity. We performed several subgroup analyses to compensate for these limitations.

5. Conclusion

We demonstrated an education-based transfusion reduction initiative is effective at decreasing perioperative blood utilization in gynecologic oncology. Transfusion reduction is a high-impact patient-centered health-care initiative with potential significant economic impact. There is an opportunity for continuous improvement, further transfusion reduction and expansion to other clinical settings.

Conflicts of interest

Dr. Meyers reports research funding from AstraZeneca for unrelated research. The others report no other conflicts of interest.

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Authors' contributions

Lauren S. Prescott: (1) Involved in conception and design of the project, acquisition of data, analysis and interpretation of data (2) Participated in drafting the article and revising it critically for important intellectual content (3) Approved the final manuscript.

Jolyn Taylor: (1) Involved in acquisition of data (2) Participated in revising the article critically for important intellectual content (3) Approved the final manuscript.

Ahmed Enbaya: (1) Involved in acquisition of data (2) Participated in revising the article critically for important intellectual content (3) Approved the final manuscript.

Claire Marten: (1) Involved in acquisition of data (2) Participated in revising the article critically for important intellectual content (3) Approved the final manuscript.

Keith Myers: (1) Involved in acquisition of data (2) Participated in revising the article critically for important intellectual content (3) Approved the final manuscript.

Larissa Meyer: (1) Involved in acquisition of data (2) Participated in revising the article critically for important intellectual content (3) Approved the final manuscript.

Pedro Ramirez: (1) Involved in acquisition of data (2) Participated in revising the article critically for important intellectual content (3) Approved the final manuscript.

Charles Levenback: (1) Involved in conception and design of the project (2) Participated in revising the article critically for important intellectual content (3) Approved the final manuscript.

Diane C. Bodurka, MD, MPH: (1) Involved in conception and design of the project (2) Participated in revising the article critically for important intellectual content (3) Approved the final manuscript.

Kathleen Schmeler: (1) Involved in conception and design of the project (2) Participated in revising the article critically for important intellectual content (3) Approved the final manuscript.

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