Preoperative Thrombocytopenia and Postoperative Outcomes after Noncardiac Surgery

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ABSTRACT

Background: Most studies examining the prognostic value of preoperative coagulation testing are too small to examine the predictive value of routine preoperative coagulation testing in patients having noncardiac surgery.

Methods: Using data from the American College of Surgeons National Surgical Quality Improvement database, the authors performed a retrospective observational study on 316,644 patients having noncardiac surgery who did not have clinical indications for preoperative coagulation testing. The authors used multivariable logistic regression analysis to explore the association between platelet count abnormalities and red cell transfusion, mortality, and major complications.

Results: Thrombocytopenia or thrombocytosis occurred in 1 in 14 patients without clinical indications for preoperative platelet testing. Patients with mild thrombocytopenia (101,000–150,000 μl^{-1}), moderate-to-severe thrombocytopenia (<100,000 μl^{-1}), and thrombocytosis (≥450,000 μl^{-1}) were significantly more likely to be transfused (7.3%, 11.8%, 8.9%, 3.1%) and had significantly higher 30-day mortality rates (1.5%, 2.6%, 0.9%, 0.5%) compared with patients with a normal platelet count. In the multivariable analyses, mild thrombocytopenia (adjusted odds ratio [AOR], 1.28; 95% CI, 1.18–1.39) and moderate-to-severe thrombocytopenia (AOR, 1.76; 95% CI, 1.49–2.08), and thrombocytosis (AOR, 1.44; 95% CI, 1.30–1.60) were associated with increased risk of blood transfusion. Mild thrombocytopenia (AOR, 1.31; 95% CI, 1.11–1.56) and moderate-to-severe thrombocytopenia (AOR, 1.93; 95% CI, 1.43–2.61) were also associated with increased risk of 30-day mortality, whereas thrombocytosis was not (AOR, 0.94; 95% CI, 0.72–1.22).

Conclusion: Platelet count abnormalities found in the course of routine preoperative screening are associated with a higher risk of blood transfusion and death. **(ANESTHESIOLOGY 2014; 120:62-75)**

PATIENTS having surgery in the United States receive nearly one quarter of the 15 million units of blood transfused annually, at a cost of nearly 800 million dollars.[1] Patients having noncardiac surgery who receive as few as 1–2 units of erythrocytes have a 30% higher risk of mortality (ROM) compared with patients who are not transfused.[2,3] There is enormous variability in transfusion practices across hospitals for both cardiac and noncardiac surgery, with greater than four-fold differences in transfusion rates between hospitals for some procedures.[4,5] Practice variation can be a red flag for low-quality health care and may be useful for identifying targets for quality improvement and cost reduction.[6] In theory, coagulation testing may help preoperatively identify patients who are at increased risk for perioperative bleeding and who may benefit from targeted interventions to reduce bleeding and blood use.

In the past, coagulation testing was widely performed to identify patients at risk for bleeding complications during surgery. However, it is now widely accepted that routine preoperative testing is not clinically useful and is needlessly expensive.[7] A recent work group convened by the American College of Physicians classified routine preoperative laboratory testing as inconsistent with "high-value, cost-conscious care."[8] According to the 2012 American Society of Anesthesiologists Task Force on Preanesthesia Evaluation, "preoperative tests should not be ordered routinely."[9] In particular, the Task Force recommends that the decision to order preoperative coagulation testing should be guided by the history and physical examination of the patient.[9] This recommendation

What We Already Know about This Topic

- The value of routine preoperative coagulation testing for noncardiac surgery remains unclear
- The investigators evaluated the association between platelet count abnormalities and transfusions and mortality in the National Surgical Quality Improvement Project registry

What This Article Tells Us That Is New

- Abnormal platelet counts were common, occurring in 1 of 14 patients
- Patients with low platelet counts were more likely to require transfusion and more likely to die

Submitted for publication February 6, 2013. Accepted for publication June 19, 2013. From the Department of Anesthesiology (L.G.G., M.P.E., S.J.L., R.W., R.Z., M.K.), Department of Pathology and Laboratory Medicine (N.B.), Department of Biostatistics and Computational Biology (C.F.), University of Rochester School of Medicine, Rochester, New York; the Department of Surgery (T.M.O.), University of Vermont College of Medicine, Burlington, Vermont; and RAND Health (A.W.D.), RAND, Boston, Massachusetts.

 Anesthesiology 2014; 120:62-75

is supported by much evidence, accumulated over the past 30 yr, suggesting that routine coagulation testing is not clinically useful for identifying patients who are more likely to develop complications after surgery.[10–19] However, most of these studies are based on relatively small patient cohorts, which may be inadequately powered to support such a conclusion.

The primary hypothesis of this exploratory study was that thrombocytopenic patients having noncardiac surgery are more likely to receive erythrocyte transfusions compared with patients with a normal platelet count. The secondary hypothesis was that thrombocytopenia is associated with a higher ROM and major complications. Our analysis only included patients without clinical indications for coagulation testing. The purpose of this study was to reexamine the predictive value of platelet testing in a large asymptomatic patient cohort in order to help inform future guideline development for coagulation testing.

Materials and Methods

Data Source

This study was conducted using data from the American College of Surgeons National Surgical Quality Improvement database (NSQIP) for patients having noncardiac surgery in 2008 and 2009. American College of Surgeons NSQIP was designed to promote quality improvement using performance feedback.[20] NSQIP includes information on patient demographics, admission source, preoperative risk factors, intraoperative transfusion, and 30-day postoperative outcomes for patients having major surgery in more than 200 participating hospitals.[21]

The data do not include information on postoperative transfusions, except to indicate if a patient has received more than 4 units of erythrocytes postoperatively, nor do they include information on platelet transfusions. Data quality is ensured through the use of trained Surgical Clinical Reviewers and auditing of participating sites. Patient data are abstracted from the medical chart, operative log, anesthesia record, from interviews with the attending surgeon, and telephone interviews with patients. A systematic sampling strategy is used to avoid bias in case selection, and to ensure a diverse surgical case mix.[21] The University of Rochester School of Medicine Institutional Review Board (Rochester, New York) determined that this study did not require Institutional Review Board review.

Study Population and Outcomes

We identified 514,087 patients who underwent general, vascular, or orthopedic surgery under general, spinal, or epidural anesthesia using Current Procedural Terminology codes.

From this sample, we identified patients without any one of the following clinical indications for preoperative platelet testing[12]: self-reported history of a bleeding disorder (vitamin K deficiency, hemophilia, thrombocytopenia, chronic anticoagulation therapy that has not been discontinued before surgery), hemorrhage (preoperative transfusion of >4 units of blood), chemotherapy in the 30 days before surgery, radiation therapy within 90 days of surgery, severe infections (systemic inflammatory response syndrome, sepsis, septic shock), liver disease (ascites, esophageal varices), steroid use, malnutrition (>10% decrease in body weight in the 6 months before surgery), renal failure, or disseminated cancer (405,343). We excluded records with no platelet counts (71,276), no hematocrits (838), procedures with work relative value units equal to zero (7,790), missing demographic information (7,780), missing American Society of Anesthesiologist Physical Status (428), and missing information on blood transfusion (547), to yield an analytic sample of 316,644 records of patients without clinical indications for coagulation testing (fig. 1). Eighty-five percent of the patients with missing platelet counts were also missing a hematocrit. It was impossible to determine whether patient records without platelet count or hematocrit information were due to patient testing not being done or due to missing data.

Statistical Analysis

The primary outcome was the receipt of any erythrocyte transfusion. Secondary outcomes were 30-day mortality and the following 30-day complications: (1) cardiac (acute myocardial infarction or cardiac arrest); (2) pulmonary (pneumonia, ventilatory support for >48 h); (3) renal (progressive renal insufficiency or acute renal failure); (4) central nervous system (cerebrovascular accident or coma lasting >24 h); (5) sepsis (sepsis or septic shock); (6) wound infection (deep incisional surgical site infection, organ or space surgical site infection, or wound dehiscence*); (6) thromboembolic (deep venous thrombosis or pulmonary embolism); and (7) graft failure.

A priori we divided the preoperative platelet count into the following categories: (1) moderate-to-severe thrombocytopenia (<100,000 μl^{-1}); (2) mild thrombocytopenia (101,000–150,000 μl^{-1}); (3) low-normal (151,000–200,000 μl^{-1}); (4) normal (201,000–450,000 μl^{-1}); and (5) thrombocytosis (≥450,000 μl^{-1}). We first performed exploratory analyses to compare patients with mild thrombocytopenia, moderate-to-severe thrombocytopenia, low-normal platelet count, normal platelet count, and increased platelet count using chi-square analysis, linear regression, or logistic regression, as appropriate. We then estimated the independent association between receipt of any erythrocyte transfusion and platelet count, using multivariable logistic regression, controlling for hematocrit, age, sex, body mass index (underweight, overweight, obesity, morbid obesity, and super obesity), admission source (home, transfer from other hospital, chronic care facility), race, inpatient status (*vs.* outpatient), emergency status, surgical complexity (work relative value units), previous operation within 30 days, and comorbidities: diabetes (oral hypoglycemics, insulin treatment), pulmonary (chronic obstructive pulmonary disease, pneumonia, mechanical ventilation

* Superficial surgical site infections were not included.

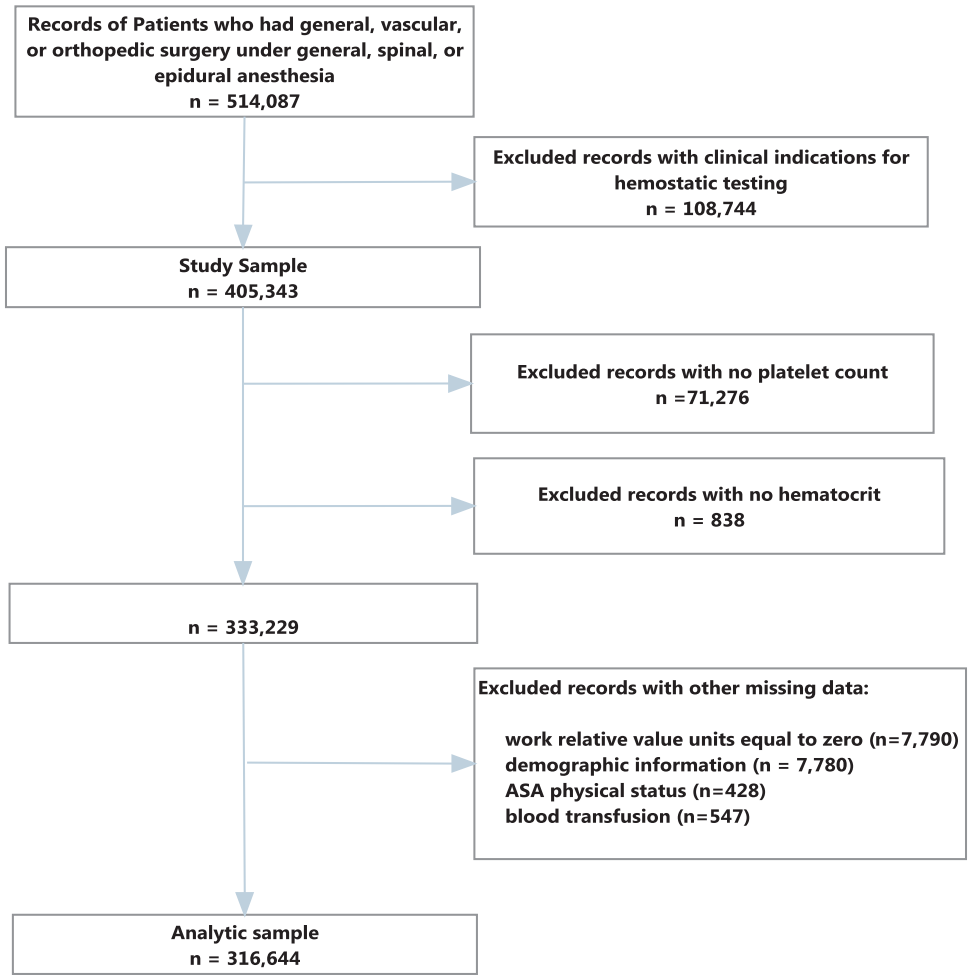

Fig. 1. Diagram illustrating selection of patients included in the data analysis. ASA = American Society of Anesthesiologists.

before surgery, dyspnea at rest, dyspnea on exertion), cardiac (congestive heart failure, myocardial infarction, angina, percutaneous coronary intervention, open heart surgery), hypertension, peripheral vascular disease, renal disease (stage 2 chronic kidney disease: glomerular filtration rate, 60–89 ml·min·1.73 m^{-2}; stage 3 chronic kidney disease: glomerular filtration rate, 30–59 ml·min·1.73 m^{-2}; stage 4 chronic kidney disease: glomerular filtration rate, 15–29 ml·min·1.73 m^{-2}),[22] central nervous system (stroke with neurologic deficit, stroke without neurologic deficit, transient ischemic attack, impaired sensorium, coma, hemiplegia, paraplegia, quadriplegia, tumor involving the central nervous system). In addition to work relative value units as a measure of surgical complexity, we included separate intercept terms for the type of procedure by Current Procedural Terminology code group (appendix 1): (1) integumentary; (2) musculoskeletal; (3) vascular; (4) hemic and lymphatic system; (5) mouth, palate, salivary glands, pharynx, adenoids, and esophagus; (6) stomach, intestines, appendix and mesentery, rectum and anus, liver, biliary tract, pancreas, abdomen, peritoneum, and omentum (nonhernia); (8) endocrine system; and (9) hernia repair (reference group).

Stratified analyses were performed in (1) low-risk patients (defined as having an ROM ≤0.5%; intermediate-risk patients (ROM: >0.5 to 3.5%); and high-risk (ROM: >3.5%). ROM was estimated using a logistic regression model based on the set of clinical risk factors described above (see Statistical Analysis, paragraph 2), omitting platelet count.

In our secondary analyses, we estimated the independent association between platelet count and (1) mortality; (2) mortality or any major complication; and (3) individual complications. In the baseline models, we used the same list of risk factors listed above. We then reestimated each model, also including blood transfusion as an additional covariate, to determine whether the effect size of the platelet count on patient outcomes would be reduced when accounting for the effects of blood transfusion. Blood transfusion was specified as a categorical variable: 0 unit erythrocytes – (reference category, 1 unit erythrocytes, 2 units erythrocytes, 3 units erythrocytes, 4 units erythrocytes, and >4 units erythrocytes).

We did not perform a sensitivity analysis to examine the association between missing platelet count and blood

transfusion because 85% of patients with missing platelet counts (n = 71,276) were also missing hematocrit values. Presumably, if clinicians elect to not order a platelet count in patients without clinical indications for platelet testing, then those patients with a missing platelet count would be less likely to require blood transfusion. Performing a sensitivity analysis in which we include patients with missing platelet counts as a separate category would not be very informative because most of these patients are also missing one of the most important confounders, the hematocrit. Without information on baseline hematocrit, this sensitivity analysis would be potentially biased. The alternative, which is to include patients with missing platelet counts and impute missing values for the platelet count (and for the hematocrit) would not be appropriate, because platelet count is the exposure variable in our analysis.

Data management and statistical analyses were performed using STATA SE/MP version 12 (STATA Corp., College Station, TX). We used multiple imputation to impute missing values for preoperative serum creatinine using the STATA implementation of the *multiple imputation by chained equations* method of multiple imputation[23] described by van Buuren *et al.*[24] We specified the imputation model using nonparsimonious linear regression estimated in the entire analytic sample. Rubin rule was used to combine parameter estimates across the five imputed data sets obtained by multiple imputation.[23] Model discrimination was assessed using the C statistic. All statistical tests were two-tailed and *P* values less than 0.05 were considered significant. We used robust variance estimators to account for the nonindependence of observations within hospitals.[25]

Results

Descriptive Statistics

The analytic sample consisted of 316,644 patients. Patients with severe thrombocytopenia tended to be older (62 *vs.* 55), female (56 *vs.* 35%), have lower hematocrits (37.2 *vs.* 39.9), and transferred from another hospital (2.62 *vs.* 0.86%) compared with patients with a normal platelet count (table 1). In general, severely thrombocytopenic patients were more likely to have a history of previous cardiac surgery (11.4 *vs.* 3.83%), percutaneous coronary intervention (7.14 *vs.* 3.91%), moderate (24.5 *vs.* 14.3%) or severe renal disease (3.84 *vs.* 1.39%), and chronic obstructive pulmonary disease (5.70 *vs.* 3.72%). Patients with severe thrombocytopenia were more likely to be at high risk (8.71 *vs.* 2.32%) and intermediate risk (39.2 *vs.* 24.0%) for 30-day mortality compared with patients with normal platelet counts.

Unadjusted Analyses

In the unadjusted analyses, moderate-to-severe thrombocytopenia (platelet count ≤100,000) was associated with a four-fold higher odds of receiving any transfusion; transfusion rate, 11.8%; odds ratio [OR], 4.15; 95% CI, 3.66–4.71; $P \leq 0.001$), and mild thrombocytopenia (platelet count, 101,000–150,000) with a 2.5-fold higher risk of receiving any transfusion (observed transfusion rate, 7.3%; OR, 2.45; 95% CI, 2.28–2.63; $P \leq 0.001$), compared with patients with normal platelet counts (observed transfusion rate, 3.1%; fig. 2, table 2, and appendix 2). Patients with thrombocytosis (platelet count, ≥450,000) had a three-fold higher unadjusted odds of receiving any blood transfusion (transfusion rate, 8.9%; OR, 3.02; 95% CI, 2.78–3.28; $P \leq 0.001$) compared with patients with a normal platelet count.

In the unadjusted analyses, patients with either mild (observed mortality rate 1.5%; OR, 3.18; 95% CI, 2.73–3.70; $P \leq 0.001$) or moderate-to-severe thrombocytopenia (observed mortality rate, 2.6%; OR, 5.49; 95% CI, 4.24–7.19; $P \leq 0.001$) were more likely to die compared with patients with normal platelet counts (observed mortality rate, 0.5%; fig. 3, table 3, and appendix 2). Patients with either mild (mortality or complication rate, 8.4%; OR, 1.71; 95% CI, 1.60–1.83; $P \leq 0.001$) or moderate-to-severe thrombocytopenia (mortality or complication rate, 12.2%; OR, 2.61; 95% CI, 2.31–2.96; $P \leq 0.001$) were also more likely to die or have a major complication compared with patients with normal platelet counts (mortality or complication rate, 5.1%). Patients with thrombocytosis were also at higher risk for death (observed mortality rate, 0.9%; OR, 1.81; 95% CI, 1.41–2.32; $P \leq 0.001$), or death or major complications (mortality or complication rate, 11.0%; OR, 2.32; 95% CI, 2.15–2.50; $P \leq 0.001$).

Patients with missing values for platelet count and/or hematocrit had lower rates of blood transfusion (0.9%), death (0.1%), and death or major complications (1.7%) compared with patients in the analytic sample (appendix 2). Patients with missing values for the platelet count and/or hematocrit were also more likely to have American Society of Anesthesiologist Physical Status I (18.2 *vs.* 8.9%) and American Society of Anesthesiologist Physical Status II (59.2 *vs.* 51.0%) compared with patients with normal platelet counts.

Results of Multivariable Analyses

We present the results of our analyses based on multiple imputation of missing values for creatinine (missing in 5.4% of the analytic sample). In the multivariable analysis, patients with mild (adjusted OR [AOR], 1.29; 95% CI, 1.18–1.39; $P \leq 0.001$) or moderate-to-severe thrombocytopenia (AOR, 1.76; 95% CI, 1.49–2.08; $P \leq 0.001$) were more likely to receive a blood transfusion compared with patients with normal platelet counts (table 2 and appendix 3). Patients with thrombocytosis (AOR, 1.44; 95% CI, 1.30–1.60; $P \leq 0.001$) were also more likely to receive blood compared with patients with normal platelet counts. Similar results were obtained when these analyses were repeated in separate strata of low-risk, intermediate-risk, and high-risk patients (table 2 and appendix 3).

Thrombocytopenia and thrombocytosis are also associated with a higher ROM. Mild thrombocytopenia (AOR, 1.31;

Table 1. Patient Demographics

Baseline Characteristics	Normal N = 241,413	Thrombocytopenia Moderate-to-severe (≤100 K), N = 2,422	Thrombocytopenia Mild (101–150 K), N = 12,739	Thrombocytopenia Low-normal (151–200 K), N = 52,496	Thrombocytosis ≥450 K, N = 7,574	*P* Value
Baseline hematocrit	39.9	37.2	39.5	40.5	35.5	≤0.001
Age, yr (median)	55	62	66	61	55	≤0.001
Male	64.6	44.4	34.0	42.7	67.1	≤0.001
Admission source						
Home	98.4	96.5	96.9	98.1	94.8	
Hospital	0.86	2.62	1.97	1.21	2.46	
Chronic care facility	0.71	0.91	1.13	0.71	2.76	≤0.001
Risk of mortality						
Low (≤0.5%)	73.7	52.1	49.8	63.0	57.8	
Intermediate (0.5–3.5%)	24.0	39.2	43.0	33.1	37.1	
High (>3.5%)	2.32	8.71	7.23	3.93	5.18	≤0.001
Do not resuscitate	0.30	0.83	0.65	0.43	0.73	≤0.001
Work RVU (median)	15.7	17.0	16.7	15.7	18.0	≤0.001
Inpatient status	66.4	78.1	74.1	67.8	83.0	≤0.001
Nonemergency cases	90.9	88.4	88.7	89.0	90.4	≤0.001
BMI (median)	29.1	27.8	27.6	28.1	27.4	≤0.001
Cardiac						
CHF 30 days before	0.31	1.07	0.89	0.47	0.74	≤0.001
MI 6 months before	0.27	1.03	0.48	0.38	0.74	≤0.001
PCI	3.91	7.14	10.6	7.47	3.84	≤0.001
Previous cardiac surgery	3.83	11.4	14.4	8.68	3.62	≤0.001
Angina 30 d before	0.44	1.03	1.09	0.70	0.34	≤0.001
Hypertension	45.4	55.7	59.2	51.3	48.2	≤0.001
Peripheral vascular disease	2.91	6.48	5.81	3.96	6.98	≤0.001
Rest pain/gangrene	1.67	3.51	2.40	1.79	5.53	≤0.001
Pulmonary						
COPD	3.72	5.70	6.32	4.53	5.37	≤0.001
Pneumonia—current	0.07	0.33	0.12	0.11	0.40	≤0.001
Dyspnea at rest	0.50	1.40	0.80	0.59	0.78	≤0.001
Dyspnea on exertion	9.18	11.6	10.9	8.88	10.4	≤0.001
Tobacco use	20.3	21.3	18.7	18.1	25.5	≤0.001
Ventilator dependent	0.07	1.36	0.38	0.11	0.13	≤0.001
Renal						
No renal disease	52.8	38.4	28.5	36.2	54.3	
Mild renal disease	25.7	28.7	30.9	31.9	24.6	
Moderate renal disease	14.3	24.5	31.4	22.9	14.3	
Severe renal disease	1.39	3.84	4.48	2.33	1.39	
missing	5.44	4.46	4.83	6.62	5.44	≤0.001
Central nervous system						
Impaired sensorium	0.14	0.87	0.46	0.24	0.44	≤0.001
Coma	0.00	0.04	0.02	0.01	0.05	0.003
Hemiplegia	0.65	0.78	1.15	0.81	1.07	≤0.001
Paraplegia	0.35	0.29	0.39	0.34	1.47	≤0.001
Quadriplegia	0.08	0.17	0.11	0.09	0.20	0.013
CVA with neurologic deficit	1.71	2.35	3.12	2.33	2.60	≤0.001
CVA without neuro deficit	1.58	3.39	3.05	2.17	2.27	≤0.001
TIA	2.50	3.67	4.60	3.67	2.52	≤0.001
Tumor involving CNS	0.06	0.04	0.08	0.04	0.08	0.498

(*Continued*)

Table 1. (*Continued*)

Baseline Characteristics	Normal	Thrombocytopenia			Thrombocytosis	
	N = 241,413	Moderate-to-severe (≤100 K), N = 2,422	Mild (101–150 K), N = 12,739	Low-normal (151–200 K), N = 52,496	≥450 K, N = 7,574	*P* Value
Diabetes						
Diabetes—oral hypoglycemic	9.52	11.5	12.8	10.6	9.68	≤0.001
Diabetes—insulin	4.81	9.33	7.50	5.13	8.61	≤0.001
Previous operation within 30 days	1.71	4.58	2.08	1.46	7.49	≤0.001
Wound infection	2.89	4.91	3.52	2.69	12.9	≤0.001

With the exception of age, hematocrit, and body mass index—all numbers are percentages. Statistical analyses comparing patients with mild thrombocytopenia, moderate-to-severe thrombocytopenia, low-normal platelet count, normal platelet count, and increased platelet count were performed using either chi-square analysis, linear regression, or logistic regression, as appropriate.

BMI = body mass index; CHF = congestive heart failure; CNS = central nervous system; COPD = chronic obstructive pulmonary disease; CVA = cerebrovascular accident; PCI = percutaneous coronary intervention; MI = myocardial infarction; neuro = neurologic; RVU = relative value units; TIA = transient ischemic attack.

95% CI, 1.11–1.56; $P \leq 0.01$) and moderate-to-severe thrombocytopenia (AOR, 1.93; 95% CI, 1.43–2.61; $P \leq 0.001$) were significantly associated with a higher ROM, whereas thrombocytosis was not (AOR, 0.94; 95% CI, 0.72–1.23; $P = 0.60$; table 3 and appendix 3). We also found that platelet count abnormalities were associated with a higher risk of the composite outcome—death or major complications. Patients with moderate-to-severe thrombocytopenia or thrombocytosis were more likely to have a major complication or die: moderate-to-severe thrombocytopenia (AOR, 1.52; 95% CI, 1.32–1.74; $P \leq 0.001$); mild thrombocytopenia (AOR, 1.12; 95% CI, 1.04–1.20; $P \leq 0.01$); or thrombocytosis (AOR, 1.36; 95% CI, 1.25–1.48; $P \leq 0.001$; table 3).

The inclusion of intraoperative and postoperative transfusions reduced the association between platelet count abnormalities and death, or death and major complications (table 3). Results obtained in stratified analyses were qualitatively similar to those obtained in the entire sample (table 3).

We also examined the association between individual complications and outcomes. Platelet count abnormalities were associated with higher risk of sepsis, pulmonary, renal, wound, and thromboembolic complications (table 4). Patients with moderate-to-severe thrombocytopenia were more likely to experience sepsis (AOR, 1.27; 95% CI, 1.12–1.45; $P \leq 0.001$), adverse pulmonary outcomes (AOR, 1.87; 95% CI, 1.50–2.32; $P \leq 0.001$), and renal complications (AOR, 2.05; 95% CI, 1.48–2.85; $P \leq 0.001$) whereas patients with thrombocytosis were more likely to experience pulmonary (AOR, 1.30; 95% CI, 1.12–1.52; $P \leq 0.001$), renal (AOR, 1.48; 95% CI, 1.14–1.91; $P \leq 0.01$), wound (AOR, 1.49; 95%

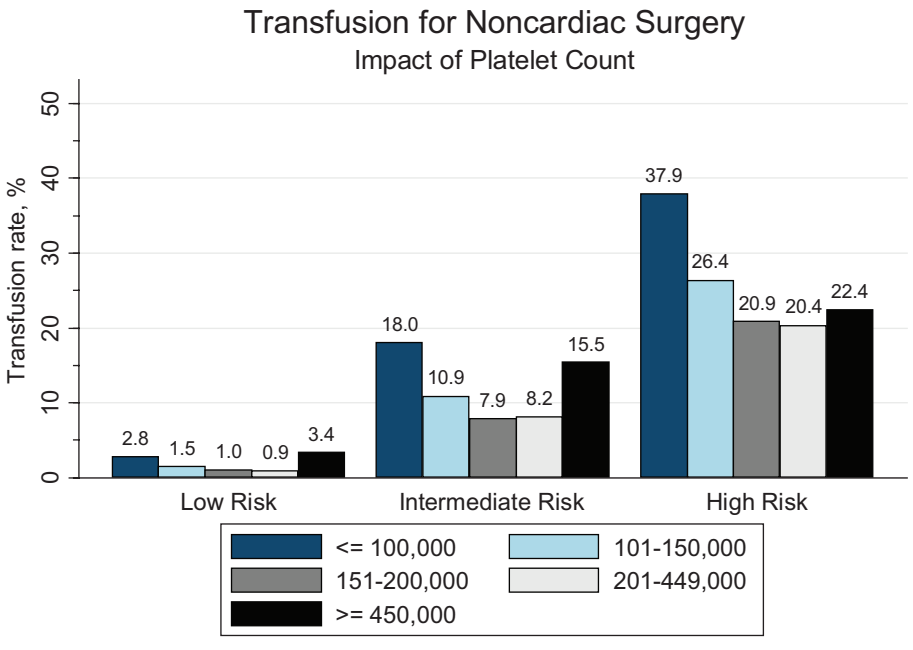

Fig. 2. Proportion of patients receiving any blood transfusion as a function of platelet count. Low-risk patients have a predicted risk of 30-day mortality ≤0.5%, intermediate risk >0.5–3.5%, and high risk >3.5%.

Table 2. Association between Preoperative Platelet Count Abnormality and Any Blood Transfusion

	Thrombocytopenia				
	Moderate-to-severe (≤100 K) N = 2,422	Mild (101–150 K) N = 12,739	Low-normal (151–200 K) N = 52,496	Thrombocytosis (≥450 K) N = 7,574	C Statistic
All patients					
OR_{unadj}	4.15 (3.66–4.71)*	2.45 (2.28–2.63)*	1.31 (1.25–1.38)*	3.02 (2.78–3.28)*	
OR_{adj}	1.76 (1.49–2.08)*	1.28 (1.18–1.39)*	1.01 (0.96–1.07)	1.44 (1.30–1.60)*	0.91
Low-risk (ROM ≤0.5%)					
OR_{unadj}	3.00 (2.14–4.21)*	1.57 (1.27–1.93)*	1.03 (0.91–1.16)	3.71 (3.13–4.40)*	
OR_{adj}	1.89 (1.29–2.76)*	1.29 (1.03–1.61)***	1.09 (0.96–1.24)	1.60 (1.32–1.94)*	0.88
Intermediate-risk (ROM >0.5–3.5%)					
OR_{unadj}	2.48 (3.10–2.94)*	1.38 (1.26–1.51)*	0.97 (0.91–1.03)	2.06 (1.85–2.29)*	
OR_{adj}	1.90 (1.55–2.33)*	1.27 (1.15–1.41)*	0.99 (0.92–1.06)	1.48 (1.30–1.68)*	0.82
High-risk (ROM >3.5%)					
OR_{unadj}	2.37 (1.78–3.15)*	1.40 (1.19–1.65)*	1.03 (0.91–1.17)	1.13 (0.88–1.45)	
OR_{adj}	1.32 (0.91–1.91)	1.26 (1.05–1.53)***	0.99 (0.86–1.14)	0.95 (0.69–1.29)	0.81

Adjusted for hematocrit, age, sex, body mass index, admission source, race, inpatient status, surgical complexity, emergency, and comorbidities.
*$P \leq 0.001$. ***$P \leq 0.05$.
OR_{adj} = adjusted odds ratio; OR_{unadj} = unadjusted odds ratio; ROM =risk-of-mortality.

CI, 1.31–1.69; $P \leq 0.001$), and thromboembolic complications (AOR, 1.74; 95% CI, 1.43–2.11; $P \leq 0.001$; table 4). All models exhibited acceptable discrimination.

Discussion

In this large observational study of more than 300,000 noncardiac surgical patients without known indications for preoperative coagulation testing, we found that patients with moderate-to-severe thrombocytopenia had a 75% higher risk of receiving a blood transfusion, and a 90% higher risk of 30-day mortality, after adjusting for preoperative risk and surgical complexity. Patients with mild thrombocytopenia had a 29% increased risk of transfusion and 31% higher ROM. Thrombocytosis was associated with a 44% increased risk of transfusion, but no increase in mortality. Thrombocytopenia and thrombocytosis were also associated with an increased risk of pulmonary, renal, sepsis, wound, and thromboembolic complications. Thrombocytopenia or thrombocytosis were not uncommon, occurring in 1 in 14 patients without clinical indications for preoperative platelet

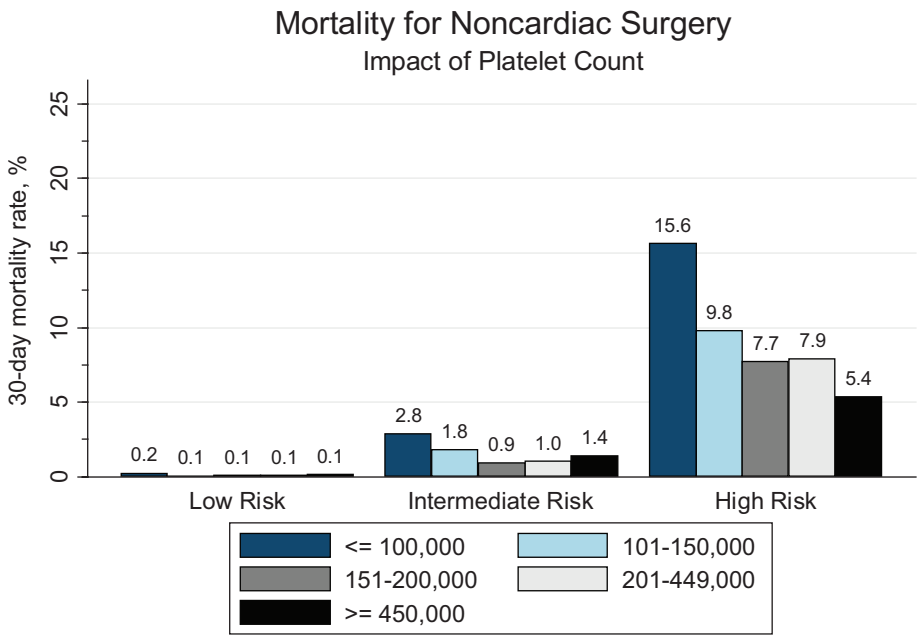

Fig. 3. Risk of 30-day mortality as a function of platelet count. Low-risk patients have a predicted risk of 30-day mortality ≤0.5%, intermediate risk >0.5–3.5%, and high risk >3.5%.

Table 3. Association between Preoperative Platelet Count Abnormality and 30-day Postoperative Outcomes

	Thrombocytopenia				
	Moderate-to-severe (≤100 K) N = 2,422	Mild (101–150 K) N = 12,739	Low-normal (151–200 K) N = 52,496	Thrombocytosis (≥450 K) N = 7,574	C Statistic
Mortality					
All patients					
OR_{unadj}	5.49 (4.24–7.10)*	3.18 (2.73–3.70)*	1.36 (1.21–1.53)*	1.81 (1.41–2.32)*	
OR_{adj}†	1.93 (1.43–2.61)*	1.31 (1.11–1.56)**	0.91 (0.80–1.04)	0.94 (0.72–1.23)	0.90
OR_{adj}‡	1.66 (1.19–2.32)**	1.25 (1.04–1.49)***	0.88 (0.77–1.01)	0.93 (0.71–1.22)	0.91
Low-risk (ROM ≤0.5%)					
OR_{unadj}	3.01 (0.96–9.46)	0.80 (0.29–2.15)	0.96 (0.62–1.46)	1.73 (0.76–3.93)	
OR_{adj}†	1.84 (0.57–5.92)	0.51 (0.19–1.40)	0.79 (0.51–1.23)	1.11 (0.47–2.60)	0.75
OR_{adj}‡	1.38 (0.37–5.09)	0.50 (0.18–1.36)	0.78 (0.50–1.22)	0.96 (0.39–2.35)	0.77
Intermediate-risk (ROM >0.5–3.5%)					
OR_{unadj}	2.88 (1.94–4.26)*	1.82 (1.47–2.26)*	0.92 (0.77–1.09)	1.38 (1.00–1.91)	
OR_{adj}†	2.58 (1.71–3.92)*	1.60 (1.28–2.00)*	0.89 (0.74–1.07)	1.08 (0.77–1.51)	0.72
OR_{adj}‡	2.01 (1.25–3.27)**	1.50 (1.19–1.88)*	0.88 (0.73–1.06)	1.06 (0.76–1.49)	0.75
High-risk (ROM >3.5%)					
OR_{unadj}	2.14 (1.46–3.14)*	1.26 (0.99–1.60)	0.97 (0.80–1.17)	0.66 (0.42–1.03)	
OR_{adj}†	1.47 (0.96–2.25)	1.11 (0.85–1.44)	0.95 (0.78–1.15)	0.65 (0.41–1.03)	0.67
OR_{adj}‡	1.35 (0.86–2.12)	1.06 (0.81–1.38)	0.91 (0.75–1.12)	0.64 (0.40–1.04)	0.72
Mortality or major complication					
All patients					
OR_{unadj}	2.61 (2.31–2.96)*	1.71 (1.60–1.83)*	1.15 (1.10–1.20)*	2.32 (2.15–2.50)*	
OR_{adj}†	1.52 (1.32–1.74)*	1.12 (1.04–1.20)**	1.00 (0.96–1.05)	1.36 (1.25–1.48)*	0.79
OR_{adj}‡	1.38 (1.19–1.59)*	1.07 (1.00–1.16)	0.99 (0.94–1.03)	1.33 (1.23–1.45)*	0.80
Low-risk (ROM ≤0.5%)					
OR_{unadj}	1.89 (1.47–2.44)*	1.28 (1.12–1.47)*	0.96 (0.9–1.03)	2.35 (2.07–2.67)*	
OR_{adj}†	1.51 (1.17–1.96)**	1.20 (1.04–1.39)***	0.99 (0.92–1.07)	1.48 (1.29–1.70)*	0.75
OR_{adj}‡	1.40 (1.08–1.83)***	1.18 (1.02–1.37)***	0.99 (0.91–1.07)	1.43 (1.24–1.64)*	0.75
Intermediate-risk (ROM >0.5–3.5%)					
OR_{unadj}	1.65 (1.38–1.96)*	1.09 (0.99–1.19)	0.93 (0.88–0.99)***	1.70 (1.54–1.89)*	
OR_{adj}†	1.57 (1.31–1.89)*	1.11 (1.01–1.21)***	1.00 (0.94–1.06)	1.32 (1.18–1.48)*	0.68
OR_{adj}‡	1.41 (1.16–1.71)*	1.06 (0.96–1.16)	1.00 (0.94–1.06)	1.27 (1.13–1.43)*	0.71
High-risk (ROM >3.5%)					
OR_{unadj}	1.84 (1.39–2.44)*	1.03 (0.88–1.20)	0.91 (0.81–1.03)	1.07 (0.85–1.35)	
OR_{adj}†	1.30 (0.95–1.77)	0.96 (0.81–1.14)	0.93 (0.82–1.05)	0.96 (0.75–1.24)	0.67
OR_{adj}‡	1.21 (0.87–1.67)	0.91 (0.76–1.09)	0.91 (0.80–1.03)	0.98 (0.76–1.26)	0.70

*$P \leq 0.001$. **$P \leq 0.01$. ***$P \leq 0.05$. † Adjusted for hematocrit, age, sex, body mass index, admission source, race, inpatient status, surgical complexity, emergency, and comorbidities. ‡ Adjusted for covariates above and blood transfusion.

OR_{adj} = adjusted odds ratio; OR_{unadj} = unadjusted odds ratio; ROM = risk-of-mortality.

testing. To our knowledge, this is the largest study to date to examine the association between platelet count and perioperative outcomes in noncardiac surgical patients without clinical indications for coagulation testing.

The ability of previous studies to evaluate the predictive value of preoperative coagulation testing was limited by low sample sizes. In a study based on 92 patients having cardiac operations, Ramsey *et al.*[11] did not find a difference in transfusion requirements in patients with abnormal preoperative coagulation tests. Rohrer *et al.*[14] prospectively studied 163 general and vascular surgery patients who received screening coagulation tests, 13 of whom had abnormal platelet counts, none of which were associated with adverse events. In a single-center retrospective study of 2,000 elective surgical patients, 60% of preoperative testing was designated as routine screening; only four of the test results were considered abnormal and none influenced perioperative care.[12] In a retrospective case-control study of 828 patients having noncardiac surgery, Ng *et al.*[18] found that coagulation abnormalities were associated with blood transfusion, but that nearly all coagulation abnormalities occurred in patients with clinical indications for testing. Houry *et al.*[16] conducted a prospective multicenter study of 3,242 general surgery patients, in which they found no changes in blood use, blood drainage, reoperations to control hemorrhage, and mortality in the 340 patients with abnormal coagulation tests and no clinical abnormalities, compared with patients with normal coagulation parameters. In

Table 4. Association between Preoperative Platelet Count Abnormality and 30-day Postoperative Complications

	Thrombocytopenia				
	Moderate-to-severe (≤100 K)	Mild (101–150 K)	Low-normal (151–200 K)	Thrombocytosis (≥450 K)	C Statistic
Cardiac complication					
OR_{unadj}	2.71 (1.83–4.01)*	2.35 (1.94–2.85)*	1.63 (1.44–1.84)*	1.73(1.30–2.28)*	
OR_{adj}†	1.02 (0.67–1.55)	0.99 (0.81–1.21)	1.08 (0.95–1.23)	1.13 (0.84–1.51)	0.87
OR_{adj}‡	0.86 (0.55–1.35)	0.96 (0.78–1.17)	1.06 (0.93–1.21)	1.10 (0.81–1.49)	0.88
Pulmonary complication					
OR_{unadj}	3.31 (2.71–4.04)*	1.90 (2.69–2.13)*	1.32 (1.23–1.43)*	2.23 (1.94–2.56)*	
OR_{adj}†	1.87 (1.50–2.32)*	1.08 (0.95–1.22)	1.06 (0.99–1.15)	1.30 (1.12–1.52)*	0.84
OR_{adj}‡	1.56 (1.23–1.98)*	1.01 (0.89–1.15)	1.05 (0.97–1.13)	1.26 (1.08–1.47)**	0.86
Renal complication					
OR_{unadj}	4.93 (3.66–6.65)*	2.95 (2.48–3.52)*	1.43 (1.25–1.63)*	2.31 (1.80–2.96)*	
OR_{adj}†	2.05 (1.48–2.85)*	1.45 (1.20–1.76)*	1.06 (0.92–1.22)	1.48 (1.14–1.91)**	0.85
OR_{adj}‡	1.71 (1.20–2.45)**	1.39 (1.14–1.69)*	1.04 (0.90–1.19)	1.44 (1.10–1.88)**	0.87
CNS complication					
OR_{unadj}	1.51 (0.72–3.21)	2.40 (1.82–3.15)*	1.48 (1.23–1.78)*	1.39 (0.89–2.17)	
OR_{adj}†	0.73 (0.34–1.60)	1.13 (0.85–1.51)	1.01 (0.83–1.22)	1.09 (0.69–1.73)	0.86
OR_{adj}‡	0.67 (0.31–1.46)	1.11 (0.83–1.48)	1.00 (0.82–1.21)	1.08 (0.68–1.71)	0.86
Sepsis complication					
OR_{unadj}	2.02 (1.62–2.51)*	1.46 (1.30–1.63)*	1.04 (0.97–1.12)	2.39 (2.13–2.70)*	
OR_{adj}†	1.17 (0.92–1.48)	1.00 (0.89–1.13)	0.95 (0.88–1.02)	1.27 (1.12–1.45)*	0.82
OR_{adj}‡	1.02 (0.80–1.32)	0.96 (0.85–1.09)	0.93 (0.87–1.01)	1.24 (1.08–1.41)**	0.83
Wound complication					
OR_{unadj}	1.63 (1.29–2.06)*	1.29 (1.15–1.45)*	0.96 (0.90–1.03)	2.06 (1.82–2.32)*	
OR_{adj}†	1.24 (0.97–1.59)	1.11 (0.98–1.26)	0.94 (0.88–1.02)	1.49 (1.31–1.69)*	0.77
OR_{adj}‡	1.15 (0.89–1.47)	1.09 (0.96–1.23)	0.94 (0.87–1.01)	1.45 (1.27–1.65)*	0.77
Thromboembolic complication					
OR_{unadj}	1.80 (1.24–2.62)**	1.54 (1.28–1.85)*	1.18 (1.06–1.32)**	2.58 (2.15–3.10)*	
OR_{adj}†	1.08 (0.74–1.58)	1.09 (0.90–1.31)	1.04 (0.93–1.17)	1.74 (1.43–2.11)*	0.76
OR_{adj}‡	0.98 (0.66–1.44)	1.06 (0.87–1.28)	1.04 (0.93–1.17)	1.70 (1.40–2.07)*	0.77
Graft failure					
OR_{unadj}	1.97 (1.04–3.68)***	1.19 (0.83–1.71)	1.02 (0.83–1.25)	2.20 (1.56–3.10)*	
OR_{adj}†	1.09 (0.55–2.11)	0.81 (0.56–1.16)	0.87 (0.70–1.08)	1.31 (0.91–1.92)	0.92
OR_{adj}‡	1.05 (0.54–2.06)	0.79 (0.54–1.14)	0.87 (0.70–1.08)	1.31 (0.90–1.92)	0.92

*$P \leq 0.001$. **$P \leq 0.01$. ***$P \leq 0.05$. † Adjusted for hematocrit, age, sex, body mass index, admission source, race, inpatient status, surgical complexity, emergency, and comorbidities. ‡ Adjusted for covariates above and blood transfusion.

CNS = central nervous system; OR_{adj} = adjusted odds ratio; OR_{unadj} = unadjusted odds ratio.

a prospective cohort of 544 elderly noncardiac surgical patients, abnormalities in platelet count occurred in 10 patients and were not associated with postoperative adverse outcomes.[17] In a single-center pilot study designed to evaluate whether indicated preoperative testing can be eliminated in ambulatory surgery, 1,026 patients were randomized to indicated preoperative testing or no testing. This pilot study did not find significant differences in adverse events between the testing and no-testing group.[19] In comparison, a larger, more recent study of 11,804 adult neurosurgery patients using the American College of Surgeons NSQIP database found that coagulation abnormalities were significantly associated with blood transfusion, reoperation, and mortality.[26] This study did not, however, examine the prognostic value of coagulation testing in patients without clinical indications for coagulation testing, and only included neurosurgical patients. With the exception of the last study, most of these studies appear to lack the statistical power to clearly establish the prognostic importance of platelet testing in surgical patients.

Our study cannot establish a causal relationship between platelet count abnormalities and death and major complications in patients having noncardiac surgery. However, our findings have face validity. Thrombocytopenic patients are more likely to bleed after surgery,[27] and patients who bleed excessively have worse outcomes. In our study, thrombocytopenic patients were 30–80% more likely to receive blood transfusion than those with normal platelet counts. Accounting for the effects of blood transfusion led to smaller increases in mortality and complications in thrombocytopenic patients. However, we could not accurately estimate the contribution of blood transfusion to the adverse effects of thrombocytopenia because we lacked detailed information on postoperative blood transfusion. There are many causes

of thrombocytopenia, including immune-mediated diseases, bone marrow disorders, and platelet sequestration.[27] In some cases, platelet abnormalities may lead to adverse outcomes after surgery, independent of the role of platelets in hemostasis, and may instead serve as a marker for other systemic diseases that impact postoperative outcomes. Our findings add to the accumulating evidence that hematologic abnormalities are important risk factors in surgical patients.[28,29]

This study has several important limitations. Although we designed this study to examine the prognostic importance of routine platelet count testing, and thus purposefully excluded patients with clinical indications for coagulation testing from our analysis, we cannot completely rule out the possibility that some of the patients who underwent coagulation testing in our sample may have had clinical indications for testing, which were not captured in our database. In addition, our analysis could only examine the prognostic value of the platelet count in patients who actually had coagulation testing, and not in the sample of patients (18% of our original study sample) who were excluded from our analysis because they did not have a recorded platelet count. These patients were less likely to be transfused or to have poor outcomes, and were also more likely to be American Society of Anesthesiologist Physical Status I or II. It is thus possible that our findings overestimate the prognostic importance of platelet testing. This concern is mitigated by the finding that although patients excluded from our analysis due to missing platelet counts were less likely to be transfused, they were also generally healthier compared with patients with normal platelet counts.

The retrospective nature of this study allows us only to conclude that there is an association between platelet count abnormalities and adverse events. We cannot conclude that platelet count abnormalities resulted in worse outcomes. More importantly, our study does not allow us to conclude that in the absence of routine coagulation screening, clinicians would have delivered less-effective care resulting in more adverse outcomes. Like other observational studies, this study may be biased due to unmeasured confounding, despite the comprehensiveness of the American College of Surgeons NSQIP database. Missing values for the serum creatinine were imputed using multiple imputation. This approach is less likely to cause bias than complete case analysis in which observations with missing data are excluded.[30] Because the public use NSQIP data file does not include hospital identifiers, we could not control for hospital effects. However, differences in hospital quality would only bias our analysis if patients with abnormal platelet counts were more likely to be admitted to lower-quality hospitals. Finally, because our data do not include information on platelet transfusions, we were unable to examine the association between platelet testing and platelet transfusion.

Given the imperative to cut healthcare costs, major stakeholders are launching initiatives to reduce unnecessary testing.[8] Our findings lead us to question whether recent recommendations[9] discouraging preoperative testing are too restrictive and perhaps based on insufficient evidence. Likewise, our study results must be interpreted with appropriate reservation, given the retrospective nature of our study. Nonetheless, healthcare systems are inherently complex and prone to patient safety errors. Although in theory, thorough histories and well-conducted physical examinations may identify many patients who will benefit the most from selective preoperative testing, a less-selective approach to coagulation testing adds some redundancy to preoperative evaluations and may identify high-risk patients who might be otherwise "missed." Given the production pressures of medical practice and the common delegation of preoperative screening to nonphysicians,[31] finding the appropriate balance between routinely testing everyone and selectively testing will require careful study.

If less-restrictive coagulation testing identifies a group of high-risk patients who would be missed if more traditional screening criteria were used, can this information be used to improve patient outcomes? It is easier to identify risk factors for poor outcomes than it is to identify effective risk-reduction strategies.[32] However, one can speculate that preoperative screening tests can improve shared decision making. Although the decision to undergo surgery is frequently driven by patient preferences, patients often lack the necessary knowledge about the risks and benefits of surgery to engage in shared decision making.[33] Truly patient-centered medicine requires that we inform patients of their personal risk of surgery based on their own personal set of risk factors, as opposed to a more general discussion based on the "typical" patient. Providing patients with personal risk information may help advance patient-centered medicine as "the next phase in health care,"[32] by allowing patients and their physicians to more accurately weigh the risks and benefits of surgery.

Conclusion

Platelet count abnormalities found in the course of "routine" preoperative screening are associated with a higher risk of blood transfusion, major complications, and death. We thus question whether recent recommendations[9] discouraging preoperative testing are too restrictive and perhaps based on insufficient evidence.

Acknowledgments

This article was supported by a grant from the Agency for Healthcare Research and Quality (RO1 HS 16737), Washington, D.C. The views presented in this article are those of the authors and may not reflect those of the Agency for Healthcare Research and Quality. The American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

Competing Interests

The authors declare no competing interests.

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Appendix 1. Categories of Procedures (n = 316,644)

CPT Range	Type of Procedure	Operations N	Operations %
10000–19999	Intergumentary	32,874	10.4
20000–29999	Musculoskeletal	31,109	9.82
34000–37799	Vascular	35,189	11.1
38000–38999	Hemic and lymphatic system	2,453	0.77
40000–43499	Mouth, palate, salivary glands, pharynx, adenoids, and esophagus	7,784	2.46
43500–49429 49900–49999	Stomach, intestines, appendix and mesentery, rectum and anus, liver, biliary tract, pancreas, abdomen, peritoneum, and omentum (nonhernia)	147,093	46.5
49490–49659	Hernia	42,657	13.5
60000–60999	Endocrine system	17,485	5.52

CPT = current procedural terminology.

Appendix 2. Unadjusted Outcomes, %

	Thrombocytopenia					
	Moderate-to-severe ≤100 K)	Mild (101–150 K)	Low-normal (151–200 K)	Normal (201–449 K)	Thrombocytosis (≥450 K)	Missing Platelet and/or Hematocrit
ASA PS						
I	3.5	4.6	8.8	8.9	3.4	18.2
II	28.5	33.3	43.6	51.0	42.7	59.2
III	56.0	53.3	42.7	37.1	48.2	21.8
IV	11.7	8.6	4.9	3.0	5.7	0.9
V	0.4	0.2	0.1	0.04	0.1	0.02
Outcomes						
Transfusion	11.8	7.3	4.1	3.1	8.9	0.89
Mortality	2.6	1.5	0.66	0.48	0.87	0.11
Mortality or complication	12.2	8.4	5.8	5.1	11.0	1.74

ASA PS = American Society of Anesthesiologists Physical Status.

Appendix 3. Model Parameters for Baseline Models

	Blood Transfusion		Death		Death or Major Complication	
Risk Factors	AOR	*P* Value	AOR	*P* Value	AOR	*P* Value
Platelet count						
≤100,000	1.76	<0.001	1.93	<0.001	1.52	<0.001
101,000–150,000	1.28	<0.001	1.31	0.002	1.12	0.003
151,000–200,000	1.01	0.659	0.91	0.156	0.99	0.802
201,000–449,000	Reference		Reference		Reference	
≥450,000	1.44	<0.001	0.94	0.635	1.36	<0.001
Hematocrit	0.87	<0.001	0.95	<0.001	0.97	<0.001
Age	1.01	<0.001	1.06	<0.001	1.02	<0.001
Male	0.77	<0.001	0.78	<0.001	0.77	<0.001
Admission source						
Home	Reference		Reference		Reference	
Hospital	1.61	<0.001	2.22	<0.001	1.56	<0.001
Chronic care facility	1.20	0.020	1.71	<0.001	1.55	<0.001

(*Continued*)

Appendix 3. (*Continued*)

	Blood Transfusion		Death		Death or Major Complication	
Risk Factors	AOR	*P* Value	AOR	*P* Value	AOR	*P* Value
Do not resuscitate	0.88	0.290	2.76	<0.001	1.54	<0.001
Race						
White	Reference		Reference		Reference	
Black	1.14	<0.001	1.01	0.895	1.14	<0.001
Asian	1.23	0.005	0.97	0.878	0.89	0.068
Native American	0.94	0.680	1.41	0.265	1.10	0.364
Hawaiian	1.36	0.178	0.53	0.461	0.95	0.799
Missing	1.04	0.352	1.03	0.760	0.96	0.157
Inpatient	5.14	<0.001	2.32	<0.001	3.79	<0.001
Emergency surgery	1.76	<0.001	2.69	<0.001	1.75	<0.001
Work relative value units	1.11	<0.001	1.05	<0.001	1.05	<0.001
Procedure type						
Integumentary	1.72	<0.001	0.35	<0.001	0.80	<0.001
Musculoskeletal	5.03	<0.001	0.77	0.093	0.48	<0.001
Vascular	7.81	<0.001	1.03	0.858	0.55	<0.001
Hemic and lymphatic system	8.64	<0.001	0.99	0.971	1.01	0.956
Mouth, palate, salivary glands, pharynx, adenoids, and esophagus	1.28	<0.001	1.04	0.859	0.77	<0.001
Stomach, intestines, appendix, rectum, liver, biliary tract, pancreas, abdomen, peritoneum, omentum	1.69	<0.001	1.32	0.039	0.86	<0.001
Hernia repair	Reference		Reference		Reference	
Endocrine system	1.47	<0.001	0.46	0.010	0.23	<0.001
Body mass index						
Underweight	1.01	0.88	1.69	<0.001	1.34	<0.001
Normal weight	Reference		Reference		Reference	
Overweight	1.01	0.72	0.74	<0.001	0.97	0.213
Obese	1.02	0.46	0.84	0.018	1.15	<0.001
Morbidly obese	0.68	<0.001	1.01	0.929	0.92	0.030
Super obese	0.55	<0.001	1.69	0.003	0.96	0.422
Cardiac						
CHF 30 days before	1.13	0.230	1.91	<0.001	1.77	<0.001
MI 6 months before	1.42	0.001	1.02	0.940	1.24	0.023
PCI	1.02	0.623	1.08	0.342	1.12	<0.001
Previous cardiac surgery	1.14	<0.001	1.09	0.228	1.03	0.360
Angina 30 days before	1.09	0.360	1.45	0.042	1.36	<0.001
Hypertension	1.11	<0.001	1.26	<0.001	1.15	<0.001
Peripheral vascular disease	1.03	0.449	1.27	0.009	1.24	<0.001
Rest pain/gangrene	0.79	<0.001	0.98	0.876	1.20	<0.001
Pulmonary						
COPD	1.25	<0.001	1.58	<0.001	1.57	<0.001
Pneumonia—current	1.38	0.124	1.70	0.036	1.80	<0.001
Dyspnea at rest	1.06	0.557	2.60	<0.001	1.67	<0.001
Dyspnea on exertion	1.07	0.027	1.23	0.003	1.12	<0.001
Tobacco use	1.20	<0.001	1.32	<0.001	1.41	<0.001
Ventilator dependent	1.65	0.006	3.58	<0.001	7.72	<0.001
Renal						
No renal disease	Reference		Reference		Reference	
Mild renal disease	1.09	0.014	1.28	0.008	0.97	0.295
Moderate renal disease	1.08	0.055	1.52	<0.001	1.10	0.004
Severe renal disease	1.03	0.614	2.79	<0.001	1.61	<0.001
Renal failure	0.95	0.776	4.13	<0.001	1.83	<0.001
Central nervous system						
Impaired sensorium	1.31	0.043	2.19	<0.001	1.96	<0.001

(*Continued*)

Appendix 3. (*Continued*)

	Blood Transfusion		Death		Death or Major Complication	
Risk Factors	AOR	*P* Value	AOR	*P* Value	AOR	*P* Value
Coma	1.26	0.626	3.43	0.034	2.27	0.093
Hemiplegia	0.94	0.557	1.23	0.253	1.10	0.242
Paraplegia	1.72	<0.001	1.96	0.006	1.39	0.001
Quadriplegia	1.16	0.625	4.08	0.001	2.01	<0.001
CVA with neurologic deficit	0.84	0.007	1.35	0.013	1.28	<0.001
CVA without neurologic deficit	0.91	0.113	1.12	0.313	1.27	<0.001
TIA	0.65	<0.001	1.04	0.658	1.02	0.592
Tumor involving CNS	1.91	0.061	1.96	0.291	1.52	0.142
Diabetes						
Diabetes—oral hypoglycemic	0.91	0.017	0.97	0.737	0.92	0.001
Diabetes—insulin	0.92	0.009	1.05	0.585	1.20	<0.001
Previous operation within 30 days	1.24	<0.001	1.15	0.270	1.37	<0.001
Wound infection	1.11	0.023	1.35	0.002	1.77	<0.001
Alcohol use	1.06	0.298	1.37	0.015	1.21	<0.001

AOR = adjusted odds ratio; CHF = congestive heart failure; CNS = central nervous system; COPD = chronic obstructive pulmonary disease; CVA = cerebrovascular accident; MI = myocardial infarction; PCI = percutaneous coronary intervention; TIA = transient ischemic attack.