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Research Paper

Associations of preoperative hematocrit and platelet count with morbidity after pathologic fracture fixation

Mohyeddine El Sayed [a], Ryley Zastrow [b], Sassine Youssef [a], Adam S. Levin [b,*]

[a] Medical University of South Carolina, 171 Ashley Avenue, Charleston, SC 29425, USA
[b] The Johns Hopkins University School of Medicine, 601 North Caroline Street, Baltimore, MD 21287, USA

HIGHLIGHTS

- Prevalence of anemia and thrombocytopenia were 61% and 18%, respectively.
- Severity of preoperative anemia correlated with stepwise increase in complications.
- Anemia and thrombocytopenia were associated with higher transfusion rates.
- Anemia was associated with cardiopulmonary, infectious, and wound complications.
- Anemia and thrombocytopenia were not associated with thromboembolic events.

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ABSTRACT

Background: Anemia and abnormal platelet count are common among patients with cancer and are associated with complications after orthopaedic procedures. We studied associations between these conditions and morbidity within 30 days after surgery for pathologic femur or humerus fracture.
Methods: We retrospectively reviewed data from the National Surgery Quality Improvement Project database for 145,030 adults following surgical fixation of a pathologic femur or humerus fracture from 2010 to 2020. Multivariable logistic regressions compared 30-day complications between patients with mild or severe anemia versus those with normal hematocrit and between patients with thrombocytopenia or thrombocytosis versus those with normal platelet count.
Results: Likelihood of extended hospitalization (≥6 days) was higher in patients with mild anemia (odds ratio [OR]: 1.47; 95 % confidence interval [CI]: 1.44, 1.51) and severe anemia (OR: 2.14; 95 % CI: 2.06, 2.23). Likelihood of all-cause morbidity was also higher among those with mild anemia (OR: 1.17; 95 % CI: 1.13, 1.21) and severe anemia (OR: 1.35; 95 % CI: 1.28, 1.42). Similarly, likelihood of extended hospitalization was higher in patients with thrombocytopenia (OR: 1.25; 95 % CI: 1.22, 1.29) and thrombocytosis (OR: 1.24; 95 % CI: 1.13, 1.36). Likelihood of all-cause morbidity was also higher for those with thrombocytopenia (OR: 1.12; 95 % CI: 1.07, 1.16) and thrombocytosis (OR: 1.21; 95 % CI: 1.07, 1.37).
Conclusion: Preoperative anemia and platelet abnormalities were potentially modifiable risk factors associated with postoperative complications following surgery for pathologic fracture.

1. Introduction

Bone is the third most common site for metastases, particularly in patients with breast, prostate, lung, thyroid, and renal carcinomas [1]. With advances in treatment, patients with metastatic disease are living longer, and consequently, are at risk for pathologic fracture [2,3]. In fact, studies have estimated that 8 %–9% of patients with bone metastases eventually sustain a pathologic femur or humerus fracture [4]. Patients undergoing operative intervention for these pathologic fractures are also at higher risk for postoperative morbidity and mortality compared to those with nonpathologic fractures [5].

Recent studies have emphasized the importance of using hematologic biomarkers such as hematocrit and platelet count for preoperative risk stratification in patients undergoing various orthopaedic surgeries

* Corresponding author at: Department of Orthopaedic Surgery, The Johns Hopkins Hospital, 601 North Caroline Street, Baltimore, MD 21287, USA.
E-mail address: alevin25@jhmi.edu (A.S. Levin).

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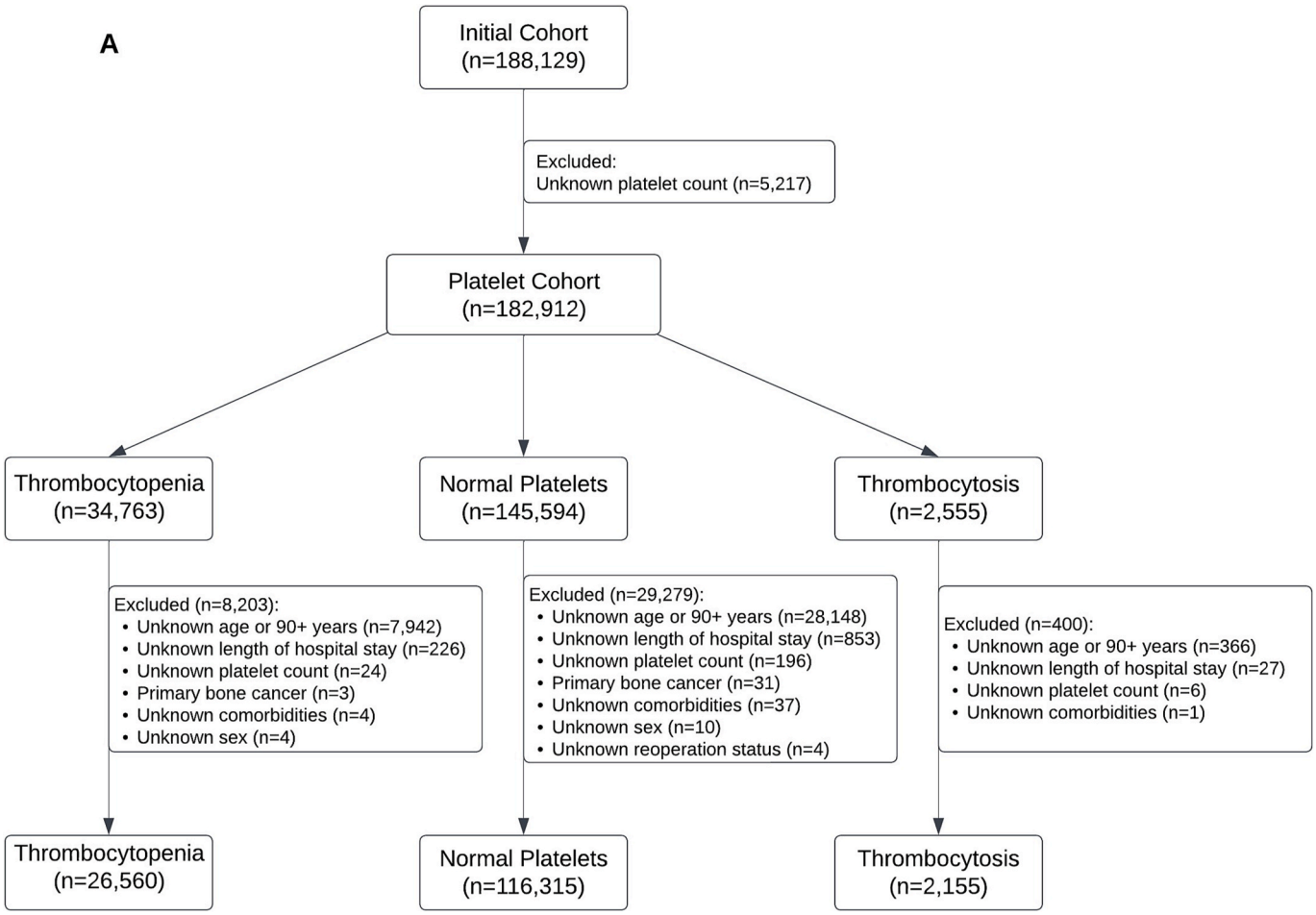

Fig. 1. CONSORT diagrams illustrating patient inclusion and exclusion criteria for the platelet cohort (A) and hematocrit cohort (B).

[6,7]. For instance, anemia has been associated with longer hospitalizations and higher rates of postoperative complications, blood transfusions, and reoperation [6,8,9]. Likewise, thrombocytopenia has been associated with infection and wound complications, while thrombocytosis has been linked to thromboembolic events [7,10–12].

Hematologic derangements occur in 30 %–90 % of patients with cancer because of treatment- or tumor-induced myelosuppression, chronic inflammation, and malnutrition [13,14]. However, there is limited evidence on the association between hematologic abnormalities and postoperative complications in patients with cancer who undergo operative intervention for pathologic fractures. Therefore, we investigated the associations of preoperative anemia and abnormal platelet counts with morbidity within 30 days after surgical management of pathologic femur or humerus fracture. We hypothesized that preoperative anemia and abnormal platelet count would be associated with higher rates of postoperative complications.

2. Methods

This retrospective cohort study was deemed exempt from approval by our institutional review board. We analyzed data from the American College of Surgeons National Surgical Quality Improvement Program database, a national registry that collects data on patient demographic characteristics, comorbidities, preoperative risk factors, and 30-day postoperative outcomes [15]. We included adults with metastatic cancer who were treated operatively for impending or complete pathologic fractures of the humerus or femur from 2010 to 2020 using *International Classification of Diseases, Ninth Revision* (ICD-9) and *Tenth Revision* (ICD-10) codes, as well as Current Procedural Terminology (CPT) codes (Supplemental Table 1). We excluded patients with a primary bone malignancy, incomplete demographic information, unknown preoperative hematocrit or platelet count, or incomplete postoperative outcome data.

We extracted data on patient demographic characteristics (age, sex, race/ethnicity); medical comorbidities (bleeding disorders, chronic obstructive pulmonary disease [COPD], congestive heart failure [CHF], diabetes, disseminated malignancy, hypertension); American Society of Anesthesiologists (ASA) classification; functional status; immunosuppressive therapy use; and preoperative hematocrit and platelet count. Postoperative outcomes were 1) extended hospital stay (defined as $\geq$ 6 days); 2) reoperation within 30 days after index surgery; 3) perioperative blood transfusion within 72 h after surgery; 4) sepsis; 5) wound complications (dehiscence, superficial or deep infection); 6) thromboembolic events (deep venous thrombosis, pulmonary embolism, stroke); 7) cardiac complications (cardiac arrest, myocardial infarction); 8) pulmonary complications (pneumonia, unplanned intubation); and 9) renal complications (acute renal insufficiency/failure, urinary tract infection). The latter 6 outcomes (sepsis through renal complications) were combined to yield an all-cause morbidity rate.

Based on previously established definitions of anemia, patients were stratified according to preoperative hematocrit into the following groups: normal (hematocrit $>$ 39 % for men and $>$ 36 % for women), mild anemia (hematocrit 29 %–39 % for men and 29 %–36 % for women), or severe anemia (hematocrit $<$ 29 % for men and women) [8]. Similarly, patients were characterized according to preoperative platelet counts into the following groups: normal (150,000–449,000/mL),

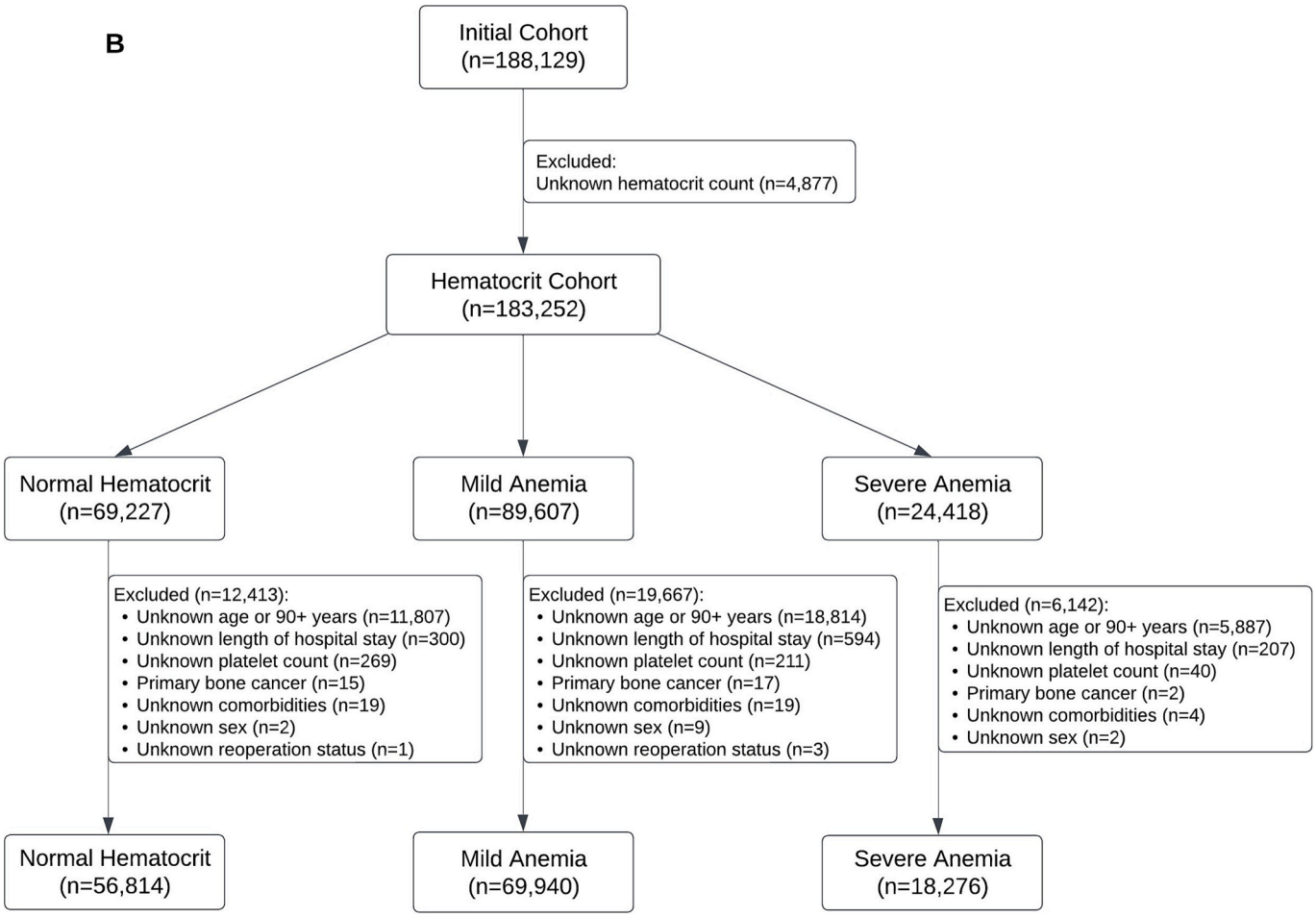

Fig. 1. (*continued*).

thrombocytopenia (<150,000/mL), or thrombocytosis (>450,000/mL) [11].

We described continuous variables using means and categorical variables using frequencies. Univariate analyses consisted of analysis of variance (ANOVA) for continuous variables and chi-squared tests for categorical variables. Effect sizes were calculated using η^2 and Cramér's V for ANOVA and chi-squared tests, respectively. Based on previous literature, we interpreted η^2 of 0–0.05 as a small effect size, 0.06–0.13 as medium, and $\geq$ 0.14 as large; and Cramér's V of $\leq$ 0.2 as a small effect size, 0.21–0.60 as medium, and $>$ 0.60 as large [16]. Multivariable logistic regressions incorporating variables with a medium or large effect size were performed to evaluate associations between preoperative hematocrit, platelet count, and postoperative outcomes. All analysis were performed using SPSS, version 22.0 (IBM Corp., Armonk, NY). $P < 0.05$ was considered significant.

3. Results

3.1. Preoperative hematocrit

Of the 188,129 patients identified, 145,030 had a recorded preoperative hematocrit and were included in the analysis (Fig. 1). Normal hematocrit was noted in 56,814 patients (39 %), mild anemia in 69,940 (48 %), and severe anemia in 18,276 (13 %). There were significant differences in all patient demographic characteristics and comorbidities between these groups (Table 1). Compared to the normal hematocrit group, the mild and severe anemia groups were older and had higher rates of all comorbidities analyzed. In addition, the mild and severe anemia groups had higher rates of immunosuppressive therapy use (6.3 %–8.6 % vs. 4.6 %), bleeding disorders (16 %–21 % vs. 11 %), abnormal platelet counts (22 %–34 % vs. 13 %), and preoperative transfusion requirements (3.0 %–21 % vs. 0.4 %) than those with a normal hematocrit (all, $p < 0.001$).

Regarding postoperative outcomes, the all-cause morbidity rate increased stepwise from 10 % in the normal hematocrit group to 13 % in the mild anemia group and 17 % in the severe anemia group (Table 2). Additionally, the length of hospital stay and frequency of each complication increased from the normal hematocrit group to the mild and severe anemia groups. In multivariable analyses, both mild and severe anemia were associated with greater odds of extended hospitalization and all preoperative complications except thromboembolic events (Table 3). In particular, mild anemia (odds ratio [OR] 3.46; 95 % confidence interval [CI]: 3.34, 3.58) and severe anemia (OR 13.9; 95 % CI:13.0, 14.2) were associated with higher odds of perioperative transfusion. Finally, mild and severe anemia conferred 1.17 times (95 % CI: 1.13, 1.21) and 1.35 times (95 % CI:1.28, 1.42) the odds of all-cause morbidity compared with normal hematocrit.

3.2. Preoperative platelet count

Of 188,129 patients, 145,030 had a recorded preoperative platelet count and were included in analysis (Fig. 1). Normal platelet counts were noted in 116,315 (80 %) patients, 26,560 (18 %) had thrombocytopenia, and 2,155 (1.5 %) had thrombocytosis. There were significant differences in all demographic characteristics and comorbidities between these groups (Table 4). For example, the thrombocytopenia group was younger (70.9 vs. 74.3–76.5 years) and had a higher rate of disseminated cancer (11 % vs. 3.6 %–4.2 %) than the other groups (both,

Table 1
Demographic and clinical characteristics of patients who underwent operative management of impending or completed pathologic fracture, stratified by preoperative hematocrit, National Surgical Quality Improvement Program database, 2010–2020.

Characteristic	N (%)			Effect Size*
	Normal Hematocrit (n = 56,814)	Mild Anemia (n = 69,940)	Severe Anemia (n = 18,276)	
Age, years	72.9 ± 0.1†	75.7 ± 0.1†	76.1 ± 0.2†	0.012
Female sex	41,561 (73)	44,176 (63)	12,461 (68)	0.099
Race				
White	41,100 (72)	49,239 (70)	13,372 (73)	0.057
African American	1,588 (2.8)	3,113 (4.5)	1,168 (6.4)	
Other	1,436 (2.5)	2,342 (3.3)	791 (4.3)	
Unknown	12,690 (22)	15,246 (22)	2,945 (16)	
Ethnicity				
Hispanic	2,510 (4.4)	3,881 (5.5)	1,369 (7.5)	
Non-Hispanic	41,364 (73)	50,859 (73)	14,139 (77)	0.049
Unknown	12,940 (23)	15,200 (22)	2,768 (15)	
Pathologic fracture site				
Humerus	5,917 (10)	4,674 (6.7)	1,007 (5.5)	0.073
Femur	50,897 (90)	65,266 (93)	17,269 (94)	
Functional status				
Independent	47,811 (84)	55,284 (79)	13,790 (75)	
Dependent	8,543 (15)	14,016 (20)	4,300 (24)	0.078
Unknown	460 (0.8)	640 (0.9)	186 (1.0)	
Body mass index value	26.8 ± 0.1†	25.9 ± 0.1†	25.5 ± 0.1†	0.006
Comorbidities				
Diabetes	9,329 (16)	16,031 (23)	4,910 (27)	0.093
Pulmonary disease	5,609 (9.9)	8,467 (12)	2,415 (13)	0.039
Current tobacco use	9,956 (18)	10,418 (15)	2,762 (15)	0.034
Heart failure	1,080 (1.9)	2,431 (3.5)	1,000 (5.5)	0.067
Hypertension	32,420 (57)	45,778 (65)	12,822 (70)	0.099
Bleeding disorder	6,178 (11)	11,164 (16.)	3,854 (21)	0.097
Disseminated cancer	1,266 (2.2)	2,953 (4.2)	1,323 (7.2)	0.083
ASA classification	2.8 ± 0†	3.0 ± 0†	3.2 ± 0†	0.044
Immunosuppressive therapy	2,614 (4.6)	4,408 (6.3)	1,567 (8.6)	0.054
Preoperative transfusion	219 (0.4)	2,110 (3.0)	3,809 (21)	0.319
Abnormal platelet count	7,504 (13)	15,071 (22)	6,140 (34)	0.164

ASA, American Society of Anesthesiologists.
* $P < 0.001$ for all comparisons.
† Expressed as mean ± standard deviation.

$p < 0.001$). Similarly, the thrombocytopenia group had higher rates of bleeding disorders (2 % vs. 11.6 %–11.9 %) and preoperative blood transfusions (8.8 % vs. 3.2 %–5.7 % compared with the other groups (both, $p < 0.001$).

Regarding postoperative outcomes, the all-cause morbidity rate was higher in the thrombocytopenia and thrombocytosis groups (both 15 %) compared with the normal platelet group (12 %) (Table 5). Furthermore, the length of hospital stay and frequency of each complication were higher in the thrombocytopenia and thrombocytosis groups compared with the normal platelet group. In multivariable analyses, both

Table 2
Postoperative complications of patients who underwent operative management of impending or completed pathologic fracture, stratified by preoperative hematocrit, National Surgical Quality Improvement Program database, 2010–2020.

Complication	N (%)			Effect Size*
	Normal Hematocrit (n = 56,814)	Mild Anemia (n = 69,940)	Severe Anemia (n = 18,276)	
Hospital stay, days	5.4 ± 0.1†	6.7 ± 0.1†	8.0 ± 0.1†	0.020
Extended hospitalization‡	17,623 (31)	30,544 (44)	10,287 (56)	0.172
Perioperative transfusion	4,950 (8.7)	17,766 (25)	10,985 (60)	0.379
Reoperation	1,247 (2.2)	1,816 (2.6)	633 (3.5)	0.025
Postoperative morbidity				
Cardiac	793 (1.4)	1,623 (2.3)	542 (3.0)	0.039
Pulmonary	1,573 (2.8)	3,273 (4.7)	1,175 (6.4)	0.062
Renal	2,071 (3.6)	3,155 (4.5)	1,091 (6.0)	0.036
Sepsis	611 (1.1)	1,269 (1.8)	570 (3.1)	0.050
Thromboembolic	1,249 (2.2)	1,616 (2.3)	507 (2.8)	0.012
Wound-related	662 (1.2)	971 (1.4)	289 (1.6)	0.012
All-cause morbidity§	5,660 (10)	9,347 (13)	3,108 (17)	0.071

* $P < 0.001$ for all comparisons.
† Expressed as mean ± standard deviation.
‡ Defined as ≥ 6 days.
§ Sum of all 6 types of morbidity listed above.

thrombocytopenia and thrombocytosis were associated with greater odds of extended hospitalization and numerous preoperative complications (Table 6). In particular, thrombocytopenia was associated with greater odds of extended hospitalization (OR 1.25; 95 % CI 1.22, 1.29) and perioperative transfusions (OR 1.33; 95 % CI: 1.29, 1.37) compared with the normal platelet group. Likewise, thrombocytosis was associated with greater odds of wound complications (OR 1.71; 95 % CI: 1.29, 2.28), sepsis (OR 1.90; 95 % CI: 1.48, 2.43), and reoperation (OR 1.68; 95 % CI: 1.36, 2.08) compared with the normal platelet group. However, thrombocytosis was associated with lower odds of receiving a perioperative transfusion (OR 0.84; 95 % CI: 0.76, 0.94) relative to the normal and thrombocytopenia groups. Finally, thrombocytopenia and thrombocytosis conferred 1.12 times (95 % CI: 1.07, 1.16) and 1.21 times (95 % CI:1.07, 1.37) the odds of all-cause morbidity compared with the normal platelet count group.

4. Discussion

In this study we examined the relationships between preoperative hematologic abnormalities and postoperative complications after surgical management of pathologic femur and humerus fractures. In these patients, hematocrit and platelet count derangements were common and were associated with greater odds of many postoperative complications. In particular, the degree of anemia correlated with a stepwise increase in nearly all postoperative morbidities we analyzed. Likewise, thrombocytopenia was associated with greater odds of perioperative transfusion, and thrombocytosis was associated with greater odds of wound issues, sepsis, and reoperation.

The prevalence of preoperative anemia was 61 %, which is higher than the prevalence of 24 %–44 % observed in orthopaedic patients who do not have cancer, likely because of treatment-induced myelosuppression, chronic inflammation, and malnutrition [13,14,17]. The overall complication rate increased from 10 % in nonanemic patients to 13 % and 17 % in mildly and severely anemic patients, respectively. Similar stepwise trends were noted for cardiac, pulmonary, renal, wound-related, and infection morbidities. Numerous studies have shown that preoperative anemia is associated with higher complication rates after hip and knee arthroplasty; shoulder and elbow surgery; and spine surgery [6,8,9,12,18–20]. Interestingly, anemia was not

Table 3
Multivariable odds of complications within 30 days after operative management of impending or completed pathologic fracture, associated with preoperative hematocrit, National Surgical Quality Improvement Program, 2010–2020.

Complication	OR	95 % CI
Extended hospitalization*		
Normal hematocrit	Referent	
Mild anemia	1.47	1.44, 1.51
Severe anemia	2.14	2.06, 2.23
Perioperative transfusion		
Normal hematocrit	Referent	
Mild anemia	3.46	3.34, 3.58
Severe anemia	13.6	13.0, 14.2
Reoperation		
Normal hematocrit	Referent	
Mild anemia	1.12	1.04, 1.20
Severe anemia	1.39	1.26, 1.54
Wound-related morbidity		
Normal hematocrit	Referent	
Mild anemia	1.12	1.01, 1.24
Severe anemia	1.14	0.98, 1.33
Cardiac morbidity		
Normal hematocrit	Referent	
Mild anemia	1.27	1.17, 1.39
Severe anemia	1.43	1.27, 1.60
Pulmonary morbidity		
Normal hematocrit	Referent	
Mild anemia	1.29	1.22, 1.38
Severe anemia	1.44	1.33, 1.57
Renal morbidity		
Normal hematocrit	Referent	
Mild anemia	1.13	1.07, 1.20
Severe anemia	1.36	1.25, 1.48
Thromboembolic morbidity		
Normal hematocrit	Referent	
Mild anemia	0.96	0.89, 1.04
Severe anemia	1.07	0.96, 1.19
Sepsis		
Normal hematocrit	Referent	
Mild anemia	1.30	1.17, 1.43
Severe anemia	1.78	1.57, 2.02
All-cause morbidity†		
Normal hematocrit	Referent	
Mild anemia	1.17	1.13, 1.21
Severe anemia	1.35	1.28, 1.42

CI, confidence interval; OR, odds ratio.
* Defined as $\geq$ 6 days.
† Sum of all 6 types of morbidity listed above.

associated with greater odds of thromboembolic events in this study. This finding is contrary to those of several previous studies, which reported higher rates of stroke and venous thromboembolism in orthopaedic patients with iron deficiency anemia [8,21]. This discrepancy may be due to the high rate of concomitant thrombocytopenia in 24 % of patients in the present study, which may alter thromboembolic potential compared to patients with iron deficiency anemia [22].

Unsurprisingly, preoperative anemia was associated with perioperative transfusion, with mild and severe anemia conferring 3.46 times and 13.6 times the odds of transfusion, respectively. Previous studies have reported similar findings for many major orthopaedic surgeries [6,23]. Postoperative blood transfusions have been linked to poorer outcomes and higher surgical site infection rates, and they carry the risk of volume overload and transfusion-related lung injuries [24,25]. Given their comorbidities, patients with cancer are at higher risk for adverse outcomes, and efforts to reduce transfusions via preoperative hematocrit optimization may prevent further postoperative morbidity [26]. Finally, anemia was associated with greater odds of reoperation, as well as longer hospitalization, consistent with prior work [9,21].

Regarding platelet count, thrombocytopenia was noted in 18 % of patients and thrombocytosis in 1.5 % of patients, which are higher rates than those in patients without cancer (6 % and 1 %, respectively) [27]. The overall complication rate of 15 % for those with thrombocytopenia or thrombocytosis was higher than the rate of 12 % for patients with normal platelet counts. Thrombocytopenia was associated with higher odds of cardiac, pulmonary, and renal morbidities, whereas thrombocytosis was associated with higher odds of sepsis and wound complications. Several studies have reported similar findings for thrombocytopenia and thrombocytosis across multiple orthopaedic surgeries [10–12,28]. Interestingly, neither thrombocytopenia nor thrombocytosis appeared to alter the odds of thromboembolic events. Prior studies have also reported no increased risk of thromboembolism in patients with thrombocytopenia [12,22]. However, the evidence regarding thromboembolism risk in patients with thrombocytosis is mixed, with some research reporting no difference in risk and other findings suggesting elevated risk [22,29].

Preoperative thrombocytopenia was associated with the need for postoperative transfusion, whereas thrombocytosis was associated with lower odds of transfusion. Though several studies have reported similar findings for thrombocytopenia, most have also reported a higher transfusion rate associated with thrombocytosis [12,29]. This discrepancy may be attributable to the smaller sample size of patients with thrombocytosis in the present study compared with prior studies, as well as the use of different platelet cutoffs to delineate thrombocytosis among studies. Finally, both thrombocytopenia and thrombocytosis were associated with higher reoperation rates and longer hospitalizations,

Table 4
Demographic and clinical characteristics of patients who underwent operative management of impending or completed pathologic fracture, stratified by preoperative platelet count, National Surgical Quality Improvement Program database, 2010–2020.

Characteristic	N (%)			Effect Size*
	Normal Platelet Count (n = 116,315)	Thrombocytopenia (n = 26,560)	Thrombocytosis (n = 2,155)	
Age, years	74.3 ± 0.1†	76.5 ± 0.1†	70.9 ± 0.6†	0.006
Female sex	81,839 (70)	14,767 (56)	1,592 (74)	0.123
Race				
White	83,006 (71)	19,296 (73)	1,409 (65)	0.019
African American	4,597 (4.0)	1,156 (4.4)	116 (5.4)	
Other	3,599 (3.1)	898 (3.4)	72 (3.3)	
Unknown	25,113 (22)	5,210 (20)	558 (26)	
Ethnicity				
Hispanic	6,053 (5.2)	1,599 (6.0)	108 (5.0)	
Non-Hispanic	85,077 (73)	19,797 (75)	1,488 (69)	0.019
Unknown	25,185 (22)	5,164 (19)	559 (26)	
Pathologic fracture site				
Humerus	10,261 (8.8)	1,026 (3.9)	311 (14)	0.076
Femur	106,054 (91)	25,534 (96)	1,844 (86)	
Functional status				
Independent	94,091 (81)	21,171 (80)	1,623 (75)	
Dependent	21,185 (18)	5,162 (19)	512 (24)	0.015
Unknown	1,039 (0.9)	227 (0.9)	20 (0.9 %)	
Body mass index value	26.3 ± 0.1†	26.1 ± 0.1†	24.6 ± 0.3†	0.001
Comorbidities				
Bleeding disorder	13,831 (12)	7,115 (27)	250 (12)	0.163
Current tobacco use	18,792 (16)	3,789 (14)	555 (26)	0.038
Diabetes	23,784 (20)	6,069 (23)	417 (19)	0.023
Disseminated cancer	4,178 (3.6)	1,120 (4.2)	244 (11)	0.050
Heart failure	3,154 (2.7)	1,289 (4.9)	68 (3.2)	0.048
Hypertension	72,075 (62)	17,690 (67)	1,255 (58)	0.039
Pulmonary disease	13,033 (11)	3,117 (12)	341 (16)	0.018
ASA classification	2.9 ± 0†	3.1 ± 0†	3.0 ± 0†	0.017
Immunosuppressive therapy	6,531 (5.6)	1,886 (7.1)	172 (8.0)	0.027
Preoperative transfusion	3,666 (3.2)	2,349 (8.8)	123 (5.7)	0.110
Preoperative anemia	67,005 (58)	19,653 (74)	1,558 (72)	0.133

ASA, American Society of Anesthesiologists.
* $P < 0.001$ for all comparisons.
† Expressed as mean ± standard deviation.

Table 5
Length of hospital stay and complications and within 30 days after operative management of impending or completed pathologic fracture, stratified by preoperative platelet count, National Surgical Quality Improvement Program database, 2010–2020.

Outcome	N (%)			Effect Size*
	Normal Platelet Count (n = 116,315)	Thrombocytopenia (n = 26,560)	Thrombocytosis (n = 2,155)	
Hospital stay, days	6.1 ± 0.1†	7.2 ± 0.1†	7.5 ± 0.3†	0.005
Extended hospitalization‡	44,307 (38)	13,138 (49)	1,009 (47)	0.091
Perioperative transfusion	24,793 (21)	8,445 (32)	463 (21)	0.096
Reoperation	2,807 (2.4)	796 (3.0)	93 (4.3)	0.020
Postoperative morbidity				
Cardiac	2,144 (1.8)	778 (2.9)	36 (1.7)	0.030
Pulmonary	4,384 (3.8)	1,534 (5.8)	103 (4.8)	0.039
Renal	4,882 (4.2)	1,341 (5.0)	94 (4.4)	0.016
Sepsis	1,772 (1.5)	610 (2.3)	68 (3.2)	0.027
Thromboembolic	2,633 (2.3)	679 (2.6)	60 (2.8)	0.008
Wound-related	1,446 (1.2)	426 (1.6)	50 (2.3)	0.016
All-cause morbidity§	13,702 (12)	4,091 (15)	322 (15)	0.043

* $P < 0.001$ for all comparisons except $p = 0.006$ for thromboembolic morbidity.
† Expressed as mean ± standard deviation.
‡ Defined as ≥ 6 days.
§ Sum of all 6 types of morbidity listed above.

consistent with prior work [27–29].

This study has several limitations. First, it is based on a large, national database that may be prone to data entry errors given its reliance upon CPT and ICD codes. Consequently, the primary malignancy could not be ascertained for most cases in this cohort because the assigned ICD-10 codes corresponded to the pathologic fracture itself rather than the primary malignancy. Additionally, the database lacks detailed clinical information regarding the type and duration of cancer treatment, which are factors that may contribute to anemia and thrombocytopenia (i.e., iron deficiency, vitamin B12 deficiency, marrow infiltrative processes), and interventions other than blood transfusion taken preoperatively to address the hematologic abnormalities we studied. Finally, the study's retrospective design prevents us from establishing causal relationships.

Our findings suggest that hematologic derangements, particularly anemia, thrombocytopenia, and thrombocytosis, are associated with greater odds of most major complications after surgical fixation of pathologic fractures. Thus, hematocrit and platelet count are two

Table 6
Multivariable odds of complications within 30 days after operative management of impending or completed pathologic fracture, associated with preoperative platelet count, National Surgical Quality Improvement Program, 2010–2020.

Complication	OR	95 % CI	P
Extended hospitalization*			
Normal platelet count	Referent		
Thrombocytopenia	1.25	1.22, 1.29	<0.001
Thrombocytosis	1.24	1.13, 1.36	<0.001
Perioperative transfusion			
Normal platelet count	Referent		
Thrombocytopenia	1.33	1.29, 1.37	<0.001
Thrombocytosis	0.84	0.76, 0.94	0.002
Reoperation			
Normal platelet count	Referent		
Thrombocytopenia	1.16	1.07, 1.26	<0.001
Thrombocytosis	1.68	1.36, 2.08	<0.001
Wound morbidity			
Normal platelet count	Referent		
Thrombocytopenia	1.17	1.04, 1.31	0.008
Thrombocytosis	1.71	1.29, 2.28	<0.001
Cardiac morbidity			
Normal platelet count	Referent		
Thrombocytopenia	1.19	1.10, 1.30	<0.001
Thrombocytosis	0.89	0.64, 1.24	0.490
Pulmonary morbidity			
Normal platelet count	Referent		
Thrombocytopenia	1.13	1.06, 1.21	<0.001
Thrombocytosis	1.13	0.92, 1.38	0.259
Renal morbidity			
Normal platelet count	Referent		
Thrombocytopenia	1.09	1.02, 1.16	0.009
Thrombocytosis	0.99	0.80, 1.22	0.903
Thromboembolic morbidity			
Normal platelet count	Referent		
Thrombocytopenia	1.05	0.96, 1.14	0.317
Thrombocytosis	1.19	0.92, 1.55	0.185
Sepsis			
Normal platelet count	Referent		
Thrombocytopenia	1.10	0.99, 1.21	0.067
Thrombocytosis	1.90	1.48, 2.43	<0.001
All-cause morbidity†			
Normal platelet count	Referent		
Thrombocytopenia	1.12	1.07, 1.16	<0.001
Thrombocytosis	1.21	1.07, 1.37	0.002

CI, confidence interval; OR, odds ratio.
* Defined as ≥ 6 days.
† Sum of all 6 types of morbidity listed above.

potentially modifiable risk factors. In fact, preoperative cutoffs for the former have been established for elective arthroplasty with standardized treatment algorithms for optimization [30,31]. Unfortunately, patients with impending or complete pathologic fractures need surgery in a timely manner to minimize further debility and maximize the quality of their remaining life, rendering protracted preoperative optimization implausible. However, future work investigating the potential role for rapid, targeted interventions, such as intravenous iron, erythropoietin, selective preoperative transfusions, and perioperative autologous cell salvage, is needed to better understand whether they can improve outcomes and reduce complications.

CRediT authorship contribution statement

Mohyeddine El Sayed: Writing – review & editing, Writing – original draft, Investigation, Conceptualization, Data curation. **Ryley Zastrow:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis. **Sassine Youssef:** Writing – review & editing, Investigation. **Adam S. Levin:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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